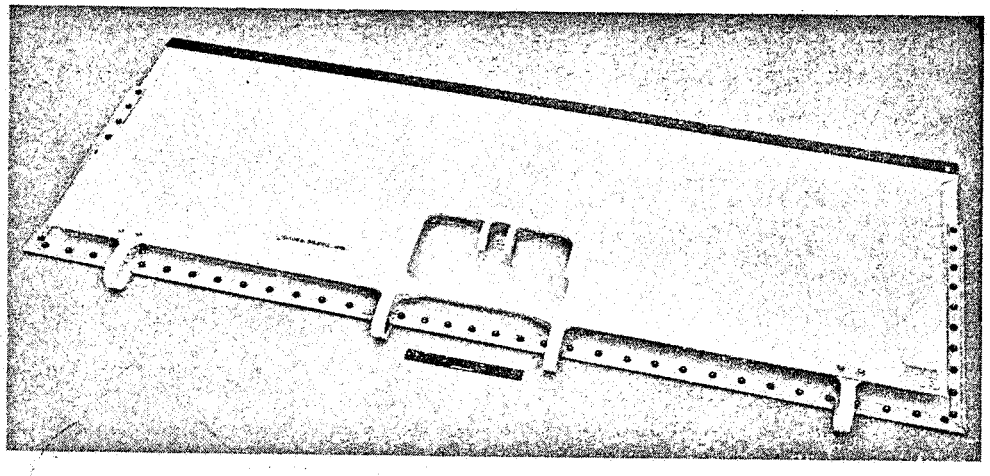
A STUDY OF THE EFFECTS OF LONG-TERM GROUND AND FLIGHT ENVIRONMENT EXPOSURE ON THE BEHAVIOR OF GRAPHITE-EPOXY SPOILERS

By Robert L. Stoecklin



Fourth Quarterly Progress Report
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16. Abstract

This quarterly report is prepared in compliance with the requirements of contract NAS1-11668 and covers the work performed from April 1, 1973 through June 30, 1973. Task I of this contract is in progress and consists of procurement and production activities required to implement the production run of 114 Boeing-designed graphite flight spoilers for the 737 airplane. The task II effort, which will include design and fabrication of an advanced-design, all-composite spoiler, is also under way. Flight spoilers from both task I and task II will be flown on commercial 737s for a period of 5 years to gather data on the environmental durability of graphite-epoxy material systems.

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SUMMARY AND PROGRAM STATUS

A STUDY OF THE EFFECTS OF LONG-TERM GROUND AND FLIGHT ENVIRONMENT EXPOSURE ON THE BEHAVIOR OF GRAPHITE-EPOXY SPOILERS

By Robert L. Stoecklin
Boeing Commercial Airplane Company

SUMMARY AND PROGRAM STATUS

This fourth quarterly progress report is submitted in accordance with the requirements of contract NAS1-11668 and covers the work performed during the period from April 1, 1973 to June 30, 1973.

The objective of this program is to produce 114 task I and eleven task II 737 flight spoilers for laboratory testing and service evaluation deployment. Four task I spoilers will be installed on each of 27 aircraft representing five major airlines operating in different environmental circumstances. These units will be monitored under actual load and environmental conditions for a period of 5 years. Selected units will be removed periodically to evaluate any material degradation as a function of time. Task II spoilers will be phased into the evaluation program as additional installations as well as replacements for task I spoilers removed for evaluation and testing.

The fourth quarter activities have been principally devoted to continued production of the task I spoilers. Heavy emphasis was placed on sustaining the production effort in order to be prepared for the spoiler distribution which began in June.

Production of detail components and procurement of vendor-fabricated details have continued to satisfactorily support the assembly process. Present schedule projections indicate that task I spoiler production will be completed in mid-August.

NASA has expanded the scope of the program by negotiating two additions to the statement of work. The first addition is task III, which will consist of fabricating and positioning six environmental exposure racks in various parts of the world to gather ground-based environmental data to support the flight data gathered from the spoilers. The second addition, task IV, will consist of fabricating 25 additional spoiler units of the task I design for NASA laboratory study. Each additional task also includes the fabrication of several flat laminate panels for NASA laboratory study.

Type certification for all three task I spoiler variations (65-76327-1, -2, and -3) has been obtained from the FAA Northwest Regional Office.

Special services agreements have been executed by four of the participating airlines as of the end of the quarter. An initial shipment of 32 spoiler units was made to these four airlines on June 26. Agreement with the fifth airline is pending.

For the task II advanced-design spoilers, continuing investigations into the producibility of the integrated composite hinge and spar components are being conducted by NASA-Langley. Feasibility has been determined and fabrication of the necessary developmental test components as well as the prototype unit itself are anticipated in the coming quarter.

DESIGN

QUALITY CONTROL

The Quality Control Research and Development effort for this quarter has been as consultant support to shop inspection personnel in interpretation of the 10-level multicolor C-scan recordings of inspected graphite spoilers. The following efforts have been completed during this reporting period:

- Completion of the NDT test procedures (see the appendix)
- Complete inspection of 56 spoiler units
- Completion of the polyurethane test block ultrasonic standard
- Rescan and radiographic inspection of static test spoilers S/N 0041 and S/N 0081.
- Surveillance of adhesive performance

All production spoiler units continue to be inspected by production Quality Control personnel to the established NDT procedures defined in the appendix. No major equipment problems occurred during this period, and the small laboratory scanner is still being used exclusively for this program. All measuring instruments used with the scanner are in full certification in conformity to established Boeing standards and the requirements of this contract.

C-scan recordings are filed with production planning papers and will be available for comparison with future recordings to be made following flight service evaluation.

To date, 45 out of 74 production spoiler units inspected (39 of 56 for this reporting period) have shown areas (within a panel) of detectable ultrasonic signal attenuation. Details of these indications are shown in table 1 along with disposition report numbers contained in Engineering records. Over 90% of all indications have occurred in the transition areas or under the -11 shim. In seven instances attenuated signals were "seen" under the -23 doublers and in five cases adjacent to the -8 center hinge fitting.

Additional adhesive is positioned around the -11 shim periphery and the ultrasonic attenuation noted in that area is attributed to the thicker adhesive bond line.

Through-transmission ultrasonic NDT methods are not capable of distinguishing between voids or disbonds when present in a localized area of a highly dampening material such as thick adhesive. Other NDT methods such as low-voltage X-ray or contact ultrasonics (i.e., Sondicator) could be used for distinction of thick adhesive areas where the production schedules permit. An investigation of rejected spoiler S/N 0034 will be made using alternate methods.

Evaluation of Static Test Spoilers

Static test spoilers S/N 0041 and S/N 0081 were rescanned after static testing. The highly attenuated areas were generally confined to the fracture areas with little or no propagation into adjacent structure. Radiographic inspection of these areas (see figs. 1 and 2) also confirmed negligible crack propagation. It is interesting to note the small edge crush on the honeycomb core in the transition areas, which also might account for sonic attenuation indications. Additional structure studies of the static test spoilers will be reported in the next quarterly report following chemical milling of these panels.

Spoiler Unit S/N 0034

Spoiler unit S/N 0034 was observed to have excessive ultrasonic signal attenuation in the center to aft honeycomb areas. Visual observation of the upper skin surface revealed three or four pockets of shallow blisters. This panel has been rejected and will be used for further NDT and subsequent destructive testing to establish structural bondline information.

ENGINEERING DESIGN

The task I engineering effort in the current reporting period has been expended principally in liaison supporting the production effort. Since the production rate averaged nearly one spoiler per day for the quarter, a close liaison effort was mandatory to preclude avoidable interruptions. Additional effort was expended in recovery operations from such problems as late adhesive delivery and expediting of prepreg tape materials. On balance, the efforts were rewarding in keeping the production effort in motion.

With the subsantial improvement in the nubmer of completed units, the accumulation of weights data has established a strong trend indication. Averaging the weights of completed units (table 2) shows that the average -1 (Union Carbide) spoiler weighs 12.73 lb, and this average is nearly identical to the 12.74 lb average for the -3 (Hercules) spoilers. The -2 (Narmco) spoilers are showing an average of 0.65 lb per spoiler heavier than the other two units. These figures are compatible with the heavier ply thickness of 0.007 in. observed on completed Narmco skins where the measured thickness of Union Carbide plies was 0.0058 in. This additional thickness of Narmco skins also accounts for the additional structural strength recorded for the Narmco test spoiler (fig. 20, p. 35, Third Quarterly Progress Report). If the Narmco ply thickness were arbitrarily reduced to 0.0058, the ultimate strength of the -2 spoiler would be reduced to:

$$\frac{0.0058}{0.007}(291\%) = 241\% \text{ DLL}$$

which closely correlates with the 246% DLL strength recorded for the -1 spoiler (Union Carbide).

As was anticipated in the early planning stages, spoiler units with significant structural discrepancies have appeared in the production process. The Third Quarterly Progress Report detailed the repair of minor damage on the edge of spoiler S/N 0005. Within this quarter, three additional units have been processed which contained major structural defects. These units were S/N 0014, 0034, and 0046. Of these three units, S/N 0014 and 0046 were deemed repairable and S/N 0034 was scrapped. Additional quality investigations are planned for 0034.

S/N 0014 contained a "blister" on the upper surface skin centered above the center hinge fitting. A repair was devised to remove and replace that portion of the damaged skin. Unfortunately, a shop error in interpretation of the repair required enlarging the repair area. A second repair was devised which covered a parallelogram-shaped area 5.40 by 4.50 in. (fig. 3). All six layers of graphite were replaced, oriented in the same manner as the original plies, with 1/4 in. steps allowed in each ply to transfer load to the replacement layers. Narmco 5209 prepreg was used for the repair material to utilize its lower (250 F) cure temperature.

The second defect occurred on S/N 0046, and was defined as a skin disbond immediately aft of the actuator attach lugs on the lower surface. Maximum distance of the disbond away from the skin edge was 0.9 in.

The repair necessarily replaced all six layers of laminate. The repair plies were oriented the same as the original plies and a tapered joint to the original layup prepared which permitted 1/4 in. peripheral lap for each ply (a total joint width of 1.50 in. for the six plies). As additional insurance, two more plies (oriented ±15°) were laid outside of contour with 1/2 in. of overlap on the existing laminate. Repair prepreg was again Narmco 5209. Figure 4 shows the uncured repair and figure 5 shows the cured and painted repair. Both repairs were designed and analyzed to develop the full potential of the fiber strength of the cured laminate.

PROCUREMENT

GRAPHITE MATERIAL

Procurement of the prepreg graphite tape material has been nearly completed in the current quarter. All scheduled shipments of Union Carbide material have been received and the entire production lot of -5 and -8 skins has been fabricated. Those skins which have not already been bonded in the second-stage layup are in production stores.

As with Union Carbide, all scheduled shipments of Narmco 5209 prepreg have also been received. The entire production lot of -6 and -9 skins has also been completed. A total of 11 Narmco spoilers (65-76327-2) remain to be completed.

The last scheduled shipment of Hercules 3501 prepreg (approximately 53 lb) is to be shipped in mid-July. This shipment will include the replacement prepreg for that portion of the 53.2 lb shipment returned under Engineering rejection. A total of 18 skins remain to be laid up from Hercules material. A total of 27 Hercules spoilers (65-76327-3) remain to be completed.

METAL DETAILS

At the close of the quarter all shipments of metal detail parts from the 737 subcontractor have been logged through the Materiel receiving area. The 737 subcontractor performed according to the established schedule, and no delays in spoiler production have occurred due to lack of detail components.

PRODUCTION

SPOILER FABRICATION

The primary effort for the current quarter has been directed toward sustaining the fabrication buildup which was in progress at the close of the previous quarter. Despite several adverse circumstances, the total of completed spoilers was increased from 13 at the beginning of the quarter to 71 as of June 30 (fig. 6). This average of nearly one spoiler completed per working day was attained despite a shortage of the EA9628 adhesive for a total of 6 weeks of the current quarter. The shortage of adhesive is reflected in the close proximity of the two bars on figure 6 representing "completed assemblies" and "bonded assemblies", with only four assemblies in the final assembly stage at the end of the quarter. The adhesive procurement problem has been brought under control with a stricter inventory control method being employed for the balance of the program.

Fabrication involving the first- and second-stage bonding operations was interrupted for a total of 6 weeks during the quarter because of a shipment of substandard EA9628 adhesive from the vendor. Adhesive stocks had been allowed to fall below the minimum level for reorder, and it was at this point that the delivery of the substandard adhesive occurred. Following quality control testing and rejection of the shipment, additional calendar time was consumed in returning the adhesive and in production and shipment of the replacement lot.

With the completion of all deliveries from the 737 subcontractor, only in-house fabrication is required to complete task I production. Current projections indicate completion of all task I fabrication in mid-August.

Completed spoiler units are packaged in individual shipping containers after final acceptance (fig. 7). The sealed boxes are held in stores awaiting shipping instructions to the participating airlines.

GRAPHITE SKIN FABRICATION

Manufacturing has made the following assessment of the skin layup experience to date concerning the several prepreg materials used in this program.

Union Carbide

Generally good quality regarding dimensional control, fiber alignment, and control of internal variations. Tack control, and variation of tack from batch to batch, appeared to be the major problems. When the tack became low, the mechanical layup had to be followed with substantial handwork to properly position and press down the tape edges.

Narmco

Since the early quality problems with the Narmco prepreg (Third Quarterly Report, p. 12), the Narmco prepreg quality has shown significant improvement. Dimensional control, straightness of tows and fibers, and tack have been evaluated as satisfactory or better. The tape performs well in the layup machine and several layups have been completed with virtually no hand rework. This prepreg has been recommended by Manufacturing for the skin material of the additional 25 spoilers required under task IV.

Hercules

The significant tape quality problems discussed in the Third Quarterly Report were coordinated with the vendor, and the corrective action by the vendor was translated into a representative 10 lb lot for evaluation by Auburn Manufacturing. The evaluation was conducted on the tape laying machine, and a considerable improvement in tape quality was noted in the set of skins made from this lot. However, subsequent shipments received in May and June have shown some deterioration in quality, notably in tack and tow alignment control. The most severe examples of the lack of tow alignment are voids produced by "wandering" tows, the most severe examples of which are shown in figure 8, where taper segments were cut from Hercules run 411. Gap defects, such as those shown in figure 9, occurred with less frequency and were easier to detect and remove. The most severe problem, however, was the low tack level. The prepreg was exceptionally dry on the face side but adhered firmly to the carrier paper, making machine layup virtually impossible. The lack of tack causes the prepreg edges to curl, and additional hand work plus vacuum bagging of each ply layer is required to properly position the prepreg.

Program management has decided to continue with the less-than-desired prepreg quality as the press of scheduled completion of the fabrication task would not permit additional developmental effort on this prepreg material.

As has been stated before, considerable effort has been expended on this program to obtain prepreg tape quality measurably better than that available from the industry prior to implementation of this program. The need for improved tape quality to permit the use of automatic tape-laying

equipment has been satisfactorily demonstrated. Continued insistence on the established level of tape quality required will be beneficial to future composite production programs.

FAA CERTIFICATION

Formal application for type certification of the three spoiler types (65-76327-1, 65-76327-2, and 65-76327-3) was made to the FAA Northwest Regional Office, together with the supporting test data (summarized in the Third Quarterly Progress Report, figures 19, 20, and 21) on April 24. Review of the application was accomplished and formal approval was received on May 9, thus completing this activity for task I.

AIRLINE COORDINATION

Boeing Contract Administration has prepared and coordinated Special Service Agreements with the participating airlines. These agreements detail the duties and responsibilities of each party for the term of the environmental exposure program. To date, four airlines have completed these agreements. The fifth agreement is pending.

An initial shipment of 32 spoilers was dispatched on June 26 to the four airlines who have executed Special Services Agreements. Initial installations on commercial 737 aircrafts are anticipated during July. Additional incremental shipments of spoilers are scheduled for July and August, with the final shipment scheduled by August 31.

GENERAL

PROGRAM SCHEDULE AND PROGRESS

Progress of the program during the current quarter has been highly satisfactory, despite the difficulties experienced. At the close of the previous quarter, it was hoped that the production rate would improve sufficiently to recover to the original production schedule (fig. 10) by June 30. The ability to process two second-stage bond assemblies per day offset the delays arising from lack of adhesive and produced a production rate of nearly one spoiler per day (which was the originally scheduled production rate). With the production delays encountered this quarter, the completion

date for the 114th unit has been extended from July 27 to August 24. Completion of production on August 24 would still permit shipment to the airlines prior to the end of August as scheduled.

A total of 58 spoilers were produced in the current quarter, excluding the one unit (S/N 0034) which was rejected for quality reasons. A total of 32 spoilers have been shipped to the participating airlines to date.

MOTION PICTURES

All footage related to task I production has been acquired. Footage related to the installation and service testing will be acquired during the coming quarter. A review of the assembled footage to date is anticipated in the coming quarter.

TASK II

Additional design and research effort by NASA-Langley on the integrated hinge fitting/spar component has been the major task II effort. NASA-Langley has informed Boeing that they desire to participate in the task II effort and have agreed to revisions in schedule which would begin the prototype fabrication in September 1973 and production of the 10 service-test spoilers early in 1974 (see fig. 11, Program Schedule).

Selection of appropriate skin and honeycomb core materials is in progress and will be completed in the coming quarter to support the revised task II schedule.

TASK III AND TASK IV

Two tasks have been added to the contract statement of work during this quarter. Task III requires fabrication and deployment of six environmental exposure racks, one at NASA-Langley and the other five at terminals of the five participating airlines. The laboratory specimens exposed on the racks would be retrieved annually over a period of 5 years and would provide ground exposure data to supplement the flight exposure data gathered from the spoiler flight program. Testing of the exposed specimens will be conducted at NASA-Langley.

Task IV is a supplemental production program of 25 task I spoilers to be used by NASA-Langley for laboratory evaluation of graphite composite structures. The spoilers will be fabricated as soon after completion of task I production as procurement lead times will permit.

Both task III and task IV also include production of a series of flat laminates made under production circumstances. These laminates will be used by NASA for laboratory study.

TABLE 1.–NDT TEST DATA–ULTRASONIC INSPECTION OF GRAPHITE-EPOXY SPOILERS[a]

Panel		Serial number	Signal attenuation	Satisfactory?	Disposition report number
65-76327-1	TE1	0001	43-48 dB under -23 doublers	Yes	
	TE2	0002	(b)	Yes	
	TE3	0003	43-54 dB trans. area (LF)	Yes	S/R 458141
	TE4	0004	43-54 dB (LF and RT), -11 shim area	Yes	S/R 930081
	TE5	0005	43-54 dB trans. area under -11 shim	Yes	S/R 458140
	TE6	0006	43-54 dB trans. area under -11 shim	Yes	S/R 458139
	TE7	0007	43-48 dB trans. area (LF) under -8 CHF	Yes	S/R 458138
	TE8	0008	43-48 dB trans. area (LF)	Yes	S/R 458137
	TE9	0009	43-48 dB (center and LF), -11 shim	Yes	S/R 930083
	TE10	0010		Yes	
	TE11	0011		Yes	
	TE12	0012	43-48 dB over entire panel	Yes	S/R 930087
	TE13	0013	43-54 dB trans. area (RT) and under -11 shim	Yes	S/R 930089
	TE14	0014	43-54 dB (LF corner) -11 shim and inside surface -11 shim	Yes	S/R 930082
	TE15	0015	43-54 dB trans. area (LF) under -11 shim	Yes	S/R 930085
	TE16	0016	43-60 dB periphery -8 CHF and -11 shim	Yes	S/R 458136
	TE17	0017	43-48 dB under -11 shim	Yes	S/R 930084
	TE18	0018	37-42 dB under -11 shim	Yes	S/R 458135
	TE19	0019		Yes	
	TE20	0020		Yes	
	TE21	0021		Yes	
	TE22	0022	43-48 dB (RT side) -11 shim	Yes	S/R 458134
	TE23	0023	43-48 dB trans. area (LF & RT) under -11 shim	Yes	S/R 458133
	TE24	0024		Yes	
	TE25	0025		Yes	
	TE26	0026	43-48 dB under -11 shim	Yes	S/R 458132
	TE27	0027	43-48 dB trans. area (LF & RT) under -11 shim	Yes	S/R 458131
	TE28	0028	43-54 dB trans. area (LF & RT) LF L/E area; under -11 shim	Yes	S/R 458130
	TE29	0029	43-48 dB trans. area (LF) under -11 shim	Yes	S/R 458129
	TE30	0030	43-54 dB trans. area (RT) center of honeycomb and under -11 shim	Yes	S/R 458128
	TE31	0031		Yes	
	TE32	0032	43-54 dB trans. area (LF & RT) under -11 shim; LF side -8 CHF	Yes	S/R 458127
	TE33	0033		(c)	
	TE34	0034	43-60 dB center honeycomb to trailing edge in distinct, irregular areas	No	Retested and rejected
	TE35	0035		(c)	
	TE36	0036		(c)	
	TE37	0037		(c)	
65-76327-1	TE38	0038		(c)	
65-76327-1R	TE1R	0001R		Yes	

TABLE 1.—CONTINUED

Panel		Serial number	Signal attenuation	Satisfactory?	Disposition report number
65-76327-2	TE1	0041	(b)	Yes	
	TE2	0042	43-54 dB inside -8 CHF	Yes	S/R 930080
	TE3	0043	43-54 dB LF side of panel	Yes	S/R 930086
	TE4	0044		Yes	
	TE5	0045		Yes	
	TE6	0046	43-54 dB trans. area (RT)	Yes	S/R 930090
	TE7	0047		Yes	
	TE8	0048	43-60 dB -8 CHF (LF) under -11 shim and -23 doublers	Yes	S/R 930092
	TE9	0049		Yes	
	TE10	0050	43-60 dB trans. area (LF and RT) under -11 shim and -23 doublers	Yes	S/R 930091
	TE11	0051		Yes	
	TE12	0052	43-54 dB trans. area (LF and RT) under -11 shim	Yes	S/R 507070
	TE13	0053		Yes	
	TE14	0054		Yes	
	TE15	0055		Yes	
	TE16	0056		Yes	
	TE17	0057	43-48 dB trans. area (LF and RT) under -11 shim and -23 doublers	Yes	S/R 507069
	TE18	0058	43-48 dB trans. area (LF and RT) under -11 shim	Yes	S/R 507068
	TE19	0059		Yes	
	TE20	0060		Yes	
	TE21	0061	43-48 dB trans. area (LF and RT) under -11 shim	Yes	S/R 507067
	TE22	0062	43-54 dB trans. area (LF and RT) under -11 shim	Yes	S/R 507066
	TE23	0063	43-54 dB trans. area (LF and RT) under -11 shim	Yes	S/R 507065
	TE24	0064	43-54 dB trans. area (LF and RT) under -11 shim	Yes	S/R 507064
	TE25	0065	43-48 dB trans. area under -11 shim and upper RT	Yes	S/R 507054
	TE26	0066	Rejected prior to NDT		
	TE27	0067	43-54 dB trans. area under -11 shim	Yes	S/R 507062
	TE28	0068	43-54 dB trans. area (LF, center, RT) under = -11 shim	Yes	S/R 507063
	TE29	0069		(c)	
	TE30	0070		(c)	
	TE31	0071	43-48 dB trans. area (LF and RT) under -11 shim	Yes	S/R 507061
	TE32	0072		(c)	
	TE33	0073			
	TE34	0074			
	TE35	0075			
	TE36	0076			
	TE37	0077			
65-76327-2	TE38	0078		(c)	
65-76327-3	TE1	0081		Yes	
	TE2	0082		Yes	
	TE3	0083		Yes	
	TE4	0084	43-60 dB over -11 shim	Yes	S/R 930088
	TE5	0085		Yes	
65-76327-3	TE6	0086		Yes	

TABLE 1.—CONCLUDED

Panel		Serial number	Signal attenuation	Satisfactory?	Disposition report number
65-76327-3	TE7	0087	43-54 dB along L/E channel trans. area (LF); -11 shim and -23 doublers	Yes	S/R 458126
	TE8	0088	43-48 dB trans. area (LF, center, RT) under -11 shim	Yes	S/R 507059
	TE9	0089	43-54 dB trans. area (LF and RT) under -11 shim	Yes	S/R 507055
	TE10	0090	43-48 dB trans. area under -11 shim	Yes	S/R 507058
	TE11	0091	43-54 dB trans. area (LF and RT) -8 CHF and -11 shim	Yes	S/R 507057
	TE12	0092	43-54 dB trans. area (LF and RT) under -11 shim	Yes	S/R 507056
	TE13	0093		(c)	
	TE14	0094	Rejected prior to NDT	—	
	TE15	0095		(c)	
	TE16	0096			
	TE17	0097			
	TE18	0098			
	TE19	0099			
	TE20	0100			
	TE21	0101			
	TE22	0102			
	TE23	0103			
	TE24	0104			
	TE25	0105			
	TE26	0106			
	TE27	0107			
	TE28	0108			
	TE29	0109			
	TE30	0110			
	TE31	0111			
	TE32	0112			
	TE33	0113			
	TE34	0114			
	TE35	0115			
	TE36	0116			
	TE37	0117			
65-76327-3	TE38	0118		(c)	

[a]1 MHz water-column-coupled through-transmission ultrasonic signal

[b]Multilevel color system inoperative; used single-level black and white recording

[c]Incomplete at this report

TABLE 2.–SPOILER WEIGHT TABULATION

Spoiler production sequence number	Spoiler serial number	Graphite tape supplier	Unpainted weight, lb	Completed weight, lb
737 production	65-46451		14.10	15.38
1	0001	Union Carbide	11.43	12.75
2	0002	Union Carbide	11.40	(a)
3	0041	Narmco	12.38	(a)
4	0003	Union Carbide	11.84	13.12
5	0004	Union Carbide	11.43	12.48
6	0005	Union Carbide	11.30	12.63
7	0006	Union Carbide	11.32	12.52
8	0007	Union Carbide		12.60
9	0042	Narmco		13.50
10	0081	Hercules	11.77	(a)
11	0008	Union Carbide		12.70
12	0009	Union Carbide		12.61
13	0010	Union Carbide		12.81
14	0043	Narmco		13.38
15	0044	Narmco		13.41
16	0045	Narmco		13.35
17	0046	Narmco		13.63
18	0011	Union Carbide		12.63
19	0015	Union Carbide		12.95
20	0014	Union Carbide		12.82
21	0016	Union Carbide		13.04
22	0013	Union Carbide		13.01
23	0012	Union Carbide		12.80
24	0017	Union Carbide		13.00
25	0083	Hercules		12.84
26	0082	Hercules		12.81
27	0020	Union Carbide		12.70
28	0047	Narmco		13.54
29	0048	Narmco		13.42
30	0084	Hercules		12.65
31	0022	Union Carbide	11.76	13.00
32	0018	Union Carbide		12.87
33	0050	Narmco		13.47
34	0021	Union Carbide		12.70
35	0056	Narmco	12.16	13.45
36	0049	Narmco		13.63
37	0019	Union Carbide	11.51	12.48
38	0051	Narmco	12.11	13.46
39	0052	Narmco		13.13
40	0085	Hercules	11.32	12.70
41	0086	Hercules	11.47	12.81
42	0025	Union Carbide	11.34	12.52
43	0026	Union Carbide	11.28	12.55
44	0058	Narmco		13.25
45	0059	Narmco	12.11	13.46
46	0057	Narmco		13.09
47	0087	Hercules		12.67
48	0054	Narmco	12.29	13.44
49	0055	Narmco	12.07	13.37

TABLE 2.–CONCLUDED

Spoiler production sequence number	Spoiler serial number	Graphite tape supplier	Unpainted weight, lb	Completed weight, lb
50	0053	Narmco	12.08	13.33
51	0023	Union Carbide		12.60
52	0024	Union Carbide		12.64
53	0060	Narmco	12.07	13.38
54	0061	Narmco		13.35
55	0088	Hercules		12.67
56	0027	Union Carbide		12.81
57	0031	Union Carbide		12.67
58	0030	Union Carbide		12.70
59	0062	Narmco		13.15
60	0063	Narmco		13.00
61	0032	Union Carbide		12.54
62	0028	Union Carbide		12.66
63	0029	Union Carbide		12.46
64	0089	Hercules		(b)
65	0065	Narmco		13.27
66	0064	Narmco		13.02
67	0067	Narmco		13.32
68	0066	Narmco		(b)
69	0090	Hercules		12.63
70	0092	Hercules		12.80
71	0091	Hercules		12.53
72	0068	Narmco		13.26
73	0034	Union Carbide		(b)
74	0001R	Union Carbide		12.86
75	0093	Hercules		(b)
76	0070	Narmco		↑
77	0069	Narmco		|
78	0094	Hercules		|
79	0071	Narmco		|
80	0095	Hercules		|
81	0096	Hercules		|
82	0074	Narmco		|
83	0072	Narmco		|
84	0104	Hercules		|
85	0105	Hercules		|
86	0106	Hercules		↓ (b)

[a]Static test article–painting and seals deleted

[b]Incomplete at report time

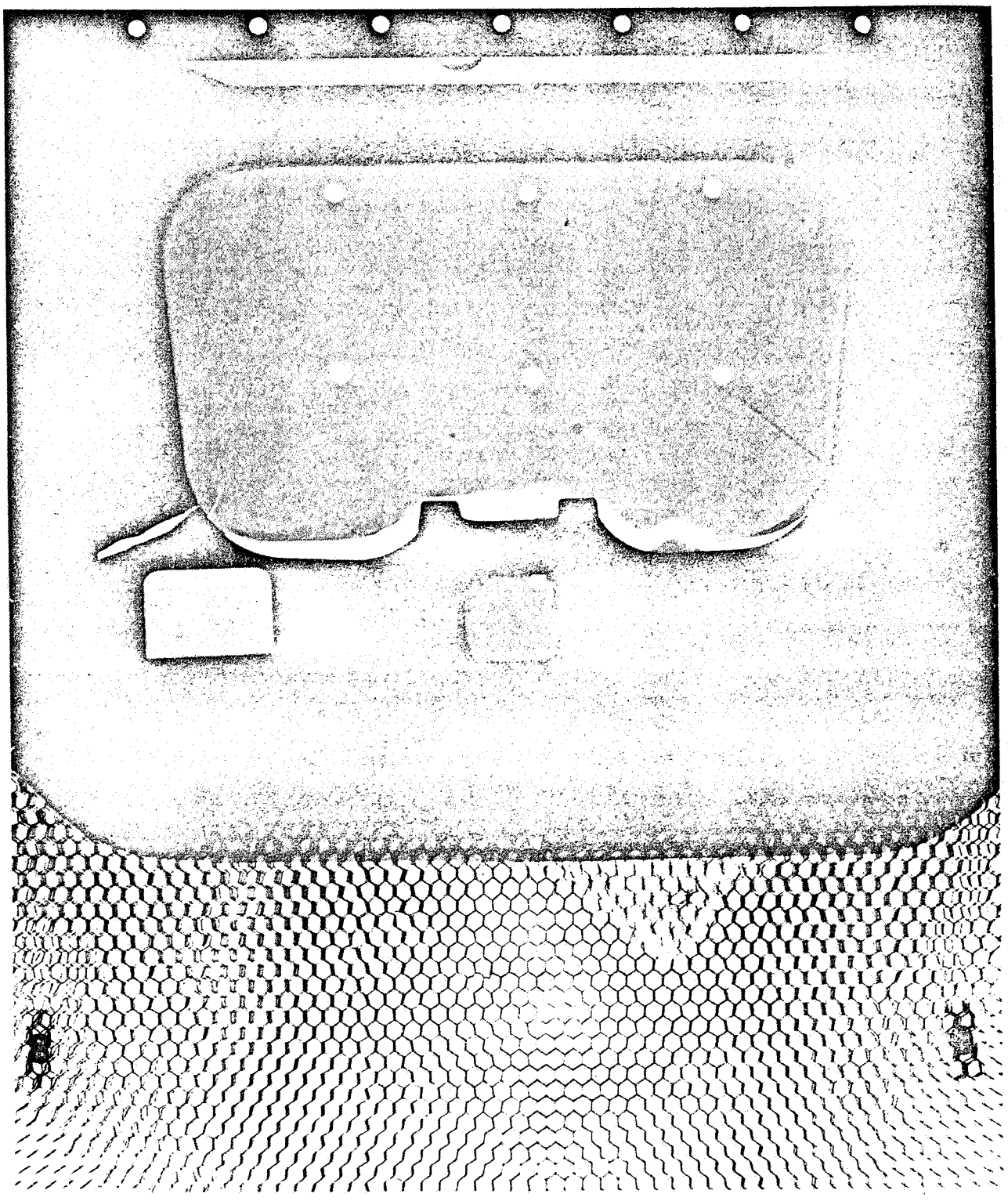

FIGURE 1.—RADIOGRAPHIC INSPECTION OF STATIC TEST SPOILER S/N 0041

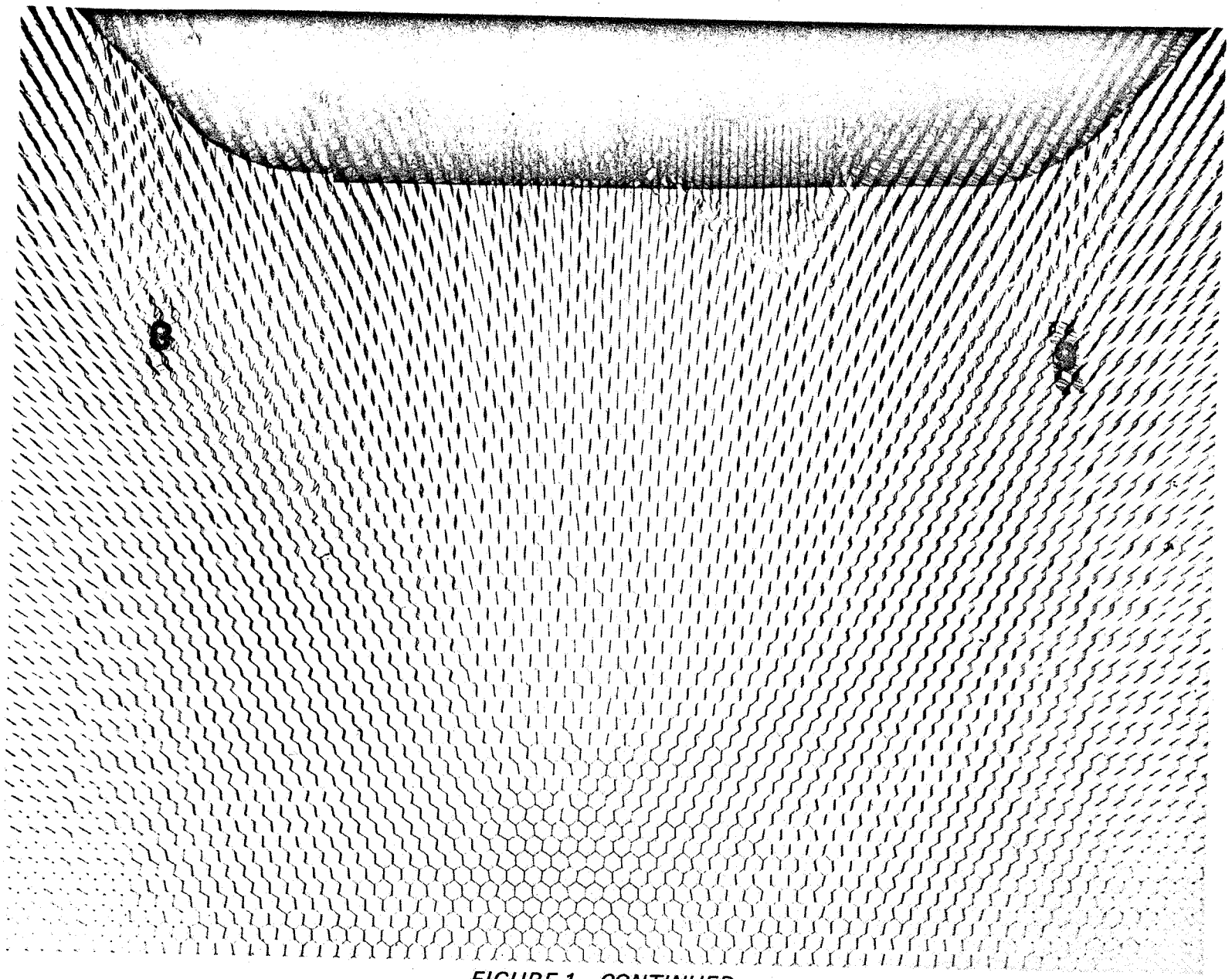

FIGURE 1.—CONTINUED

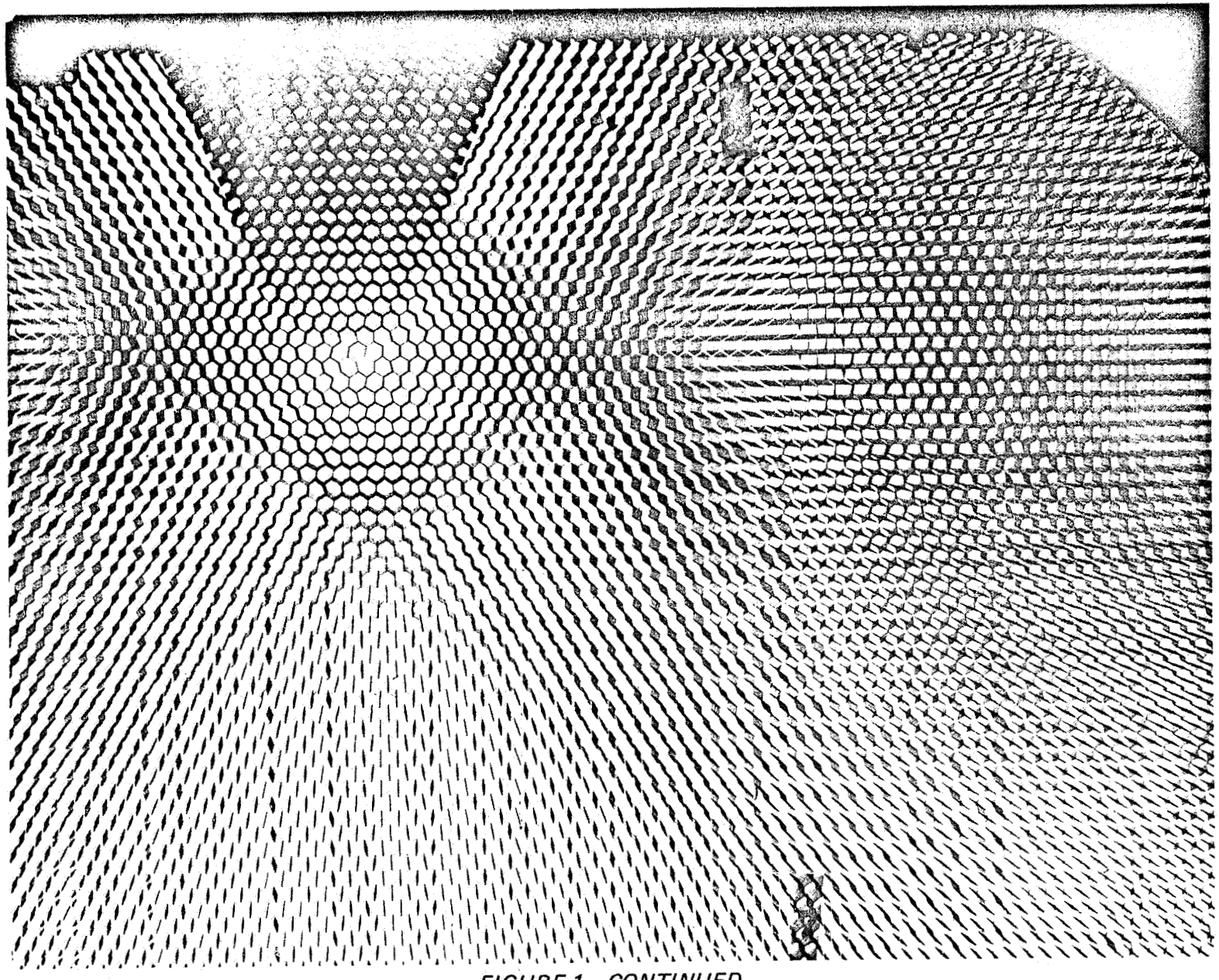

FIGURE 1.—CONTINUED

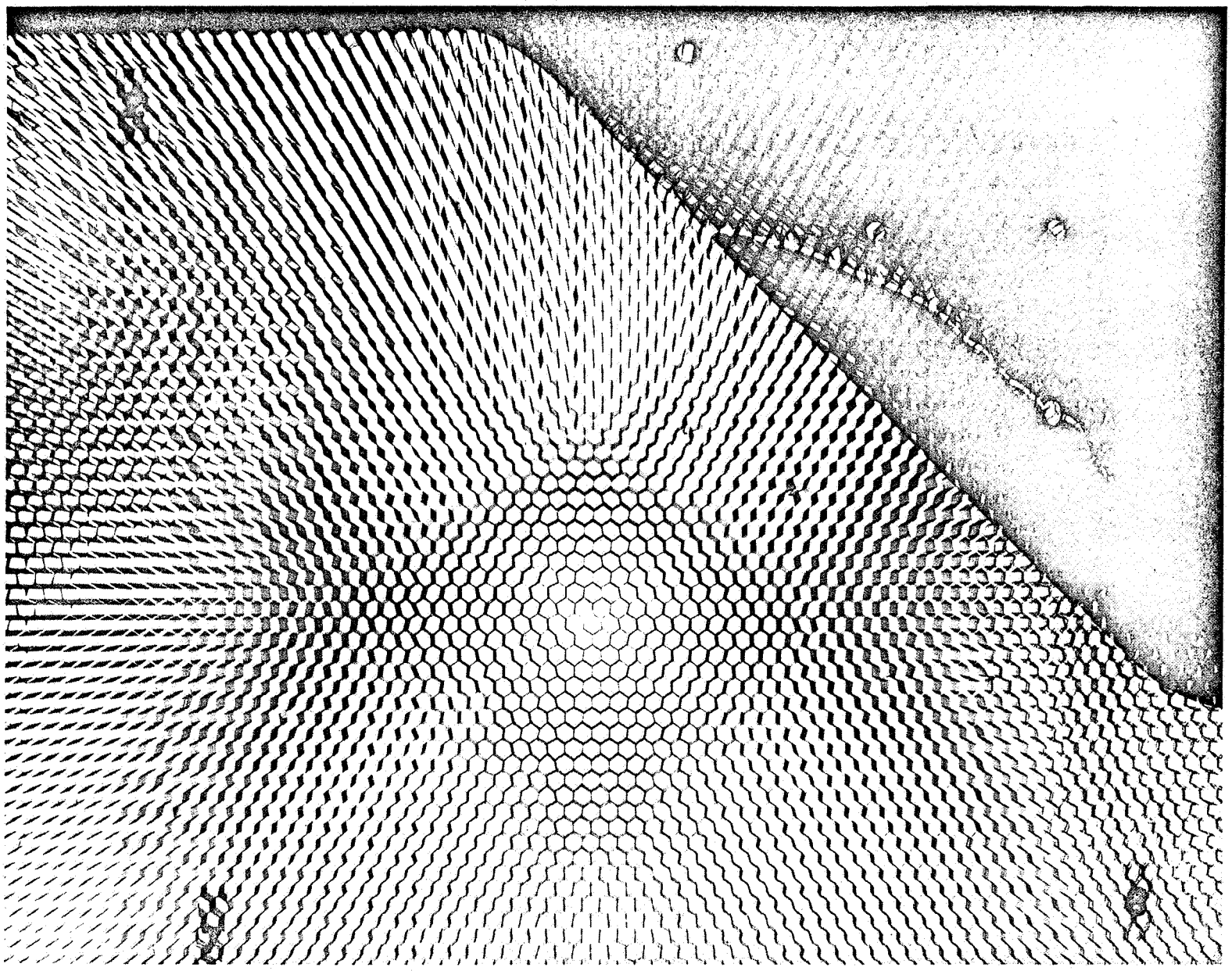

FIGURE 1.—CONTINUED

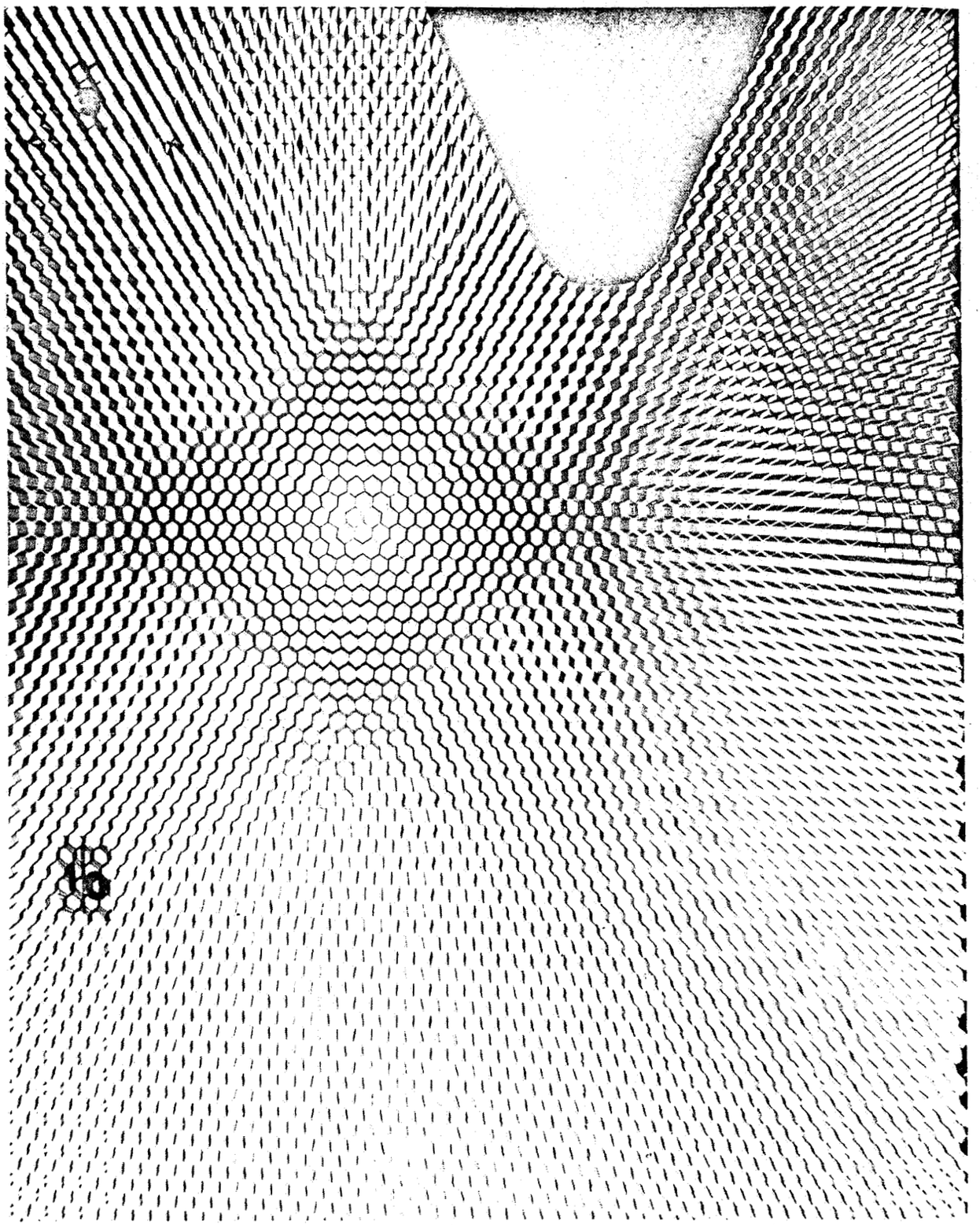

FIGURE 1.—CONTINUED

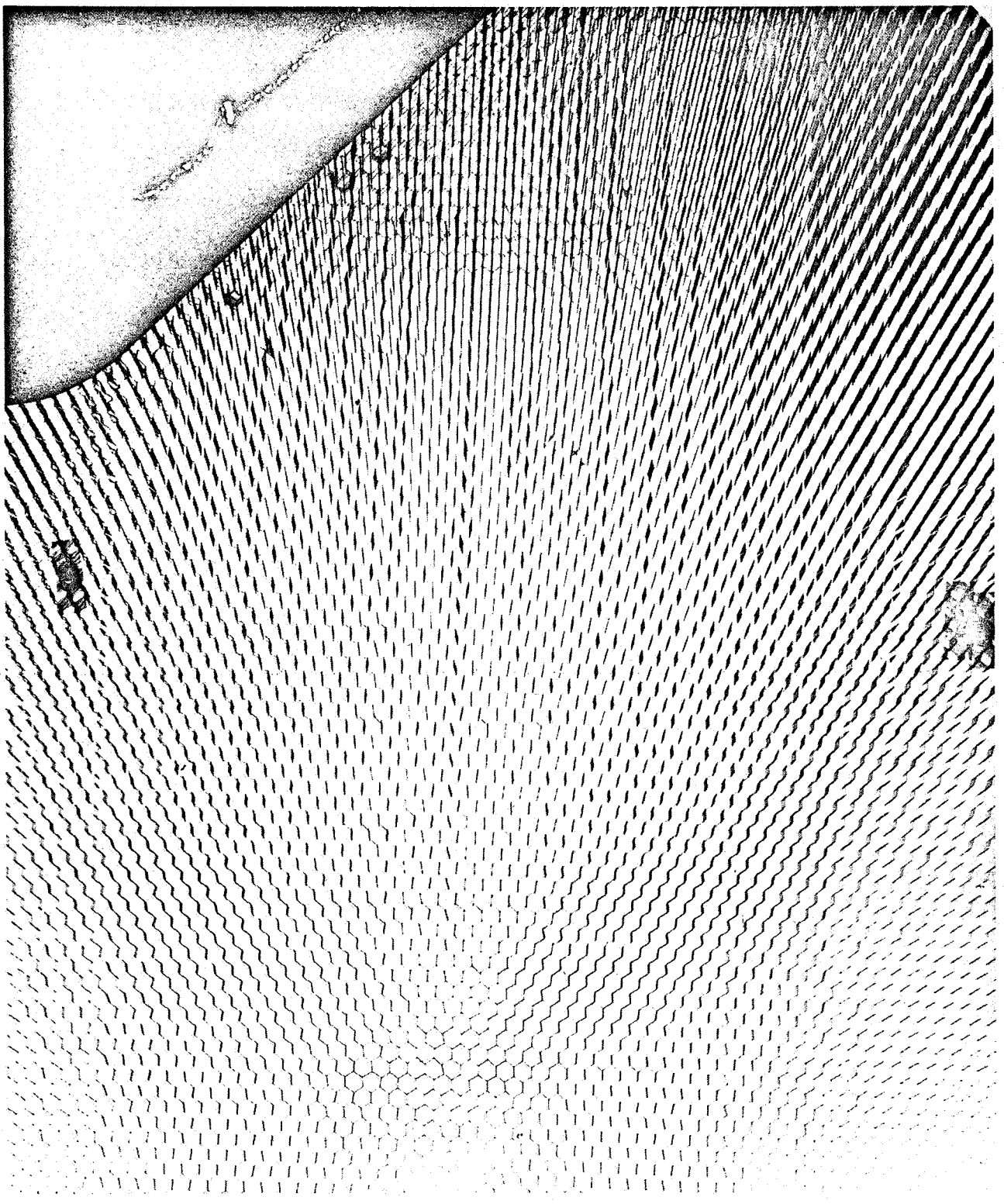

FIGURE 1.—CONTINUED

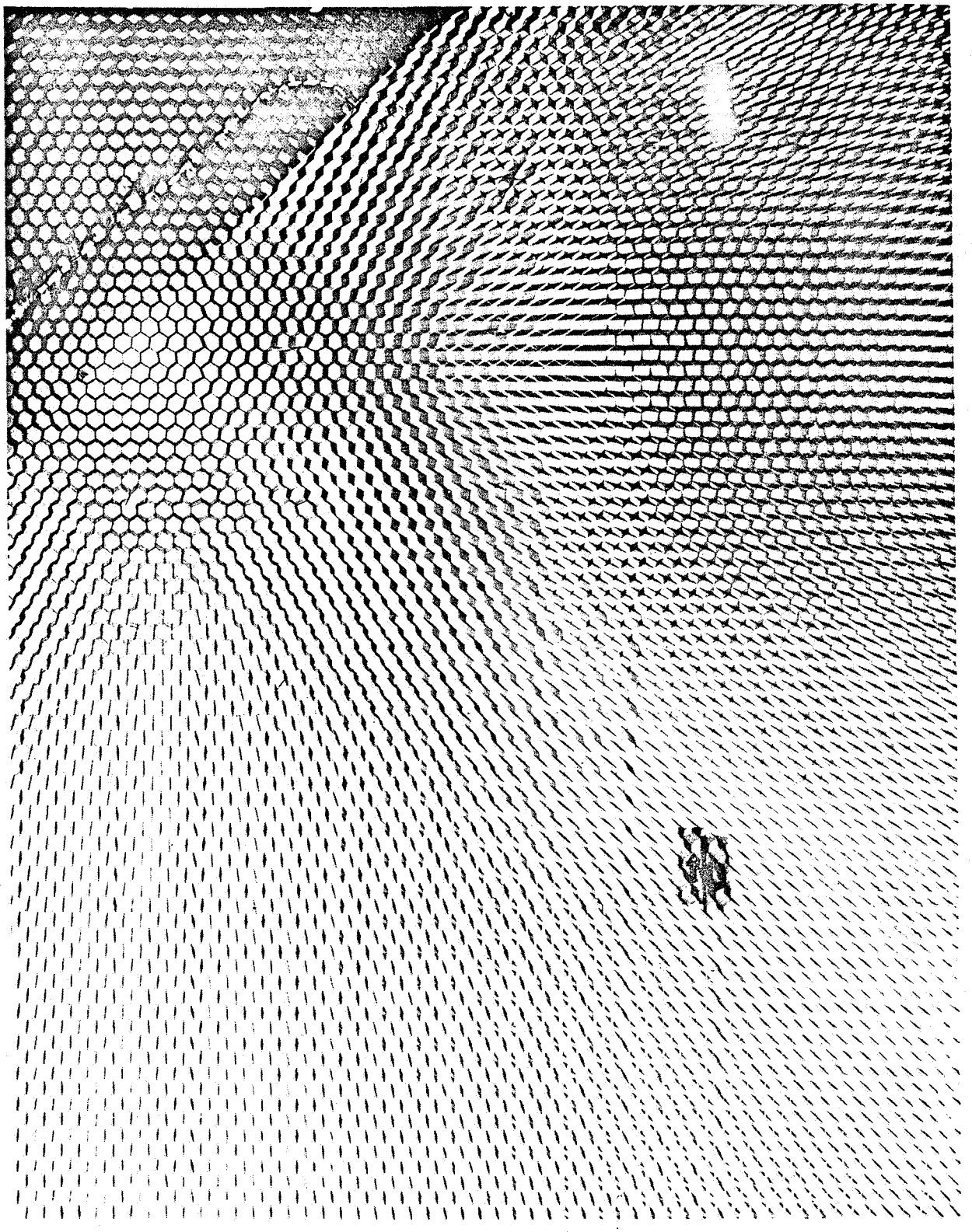

FIGURE 1.—CONCLUDED

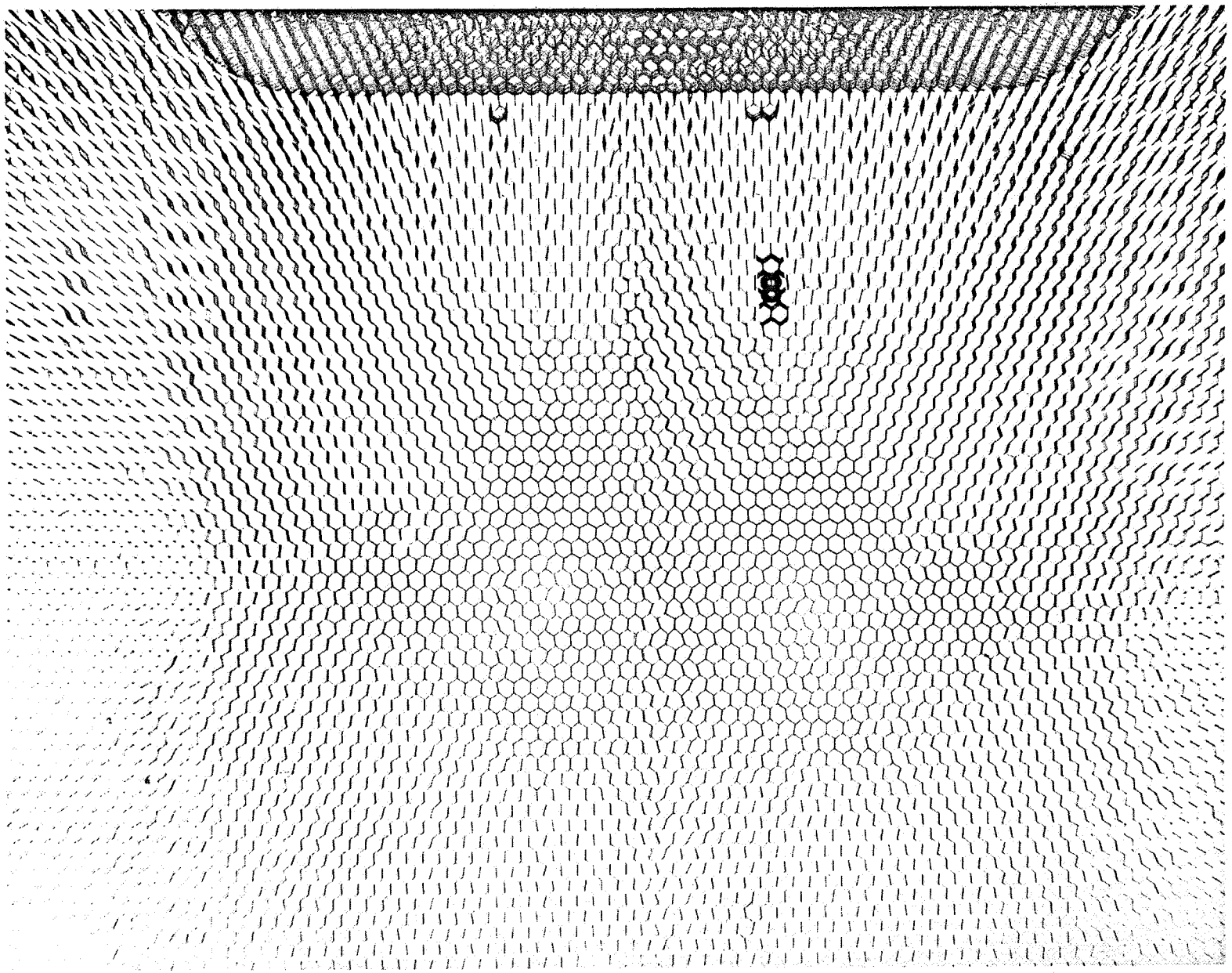

FIGURE 2.—RADIOGRAPHIC INSPECTION OF STATIC TEST SPOILER S/N 0081

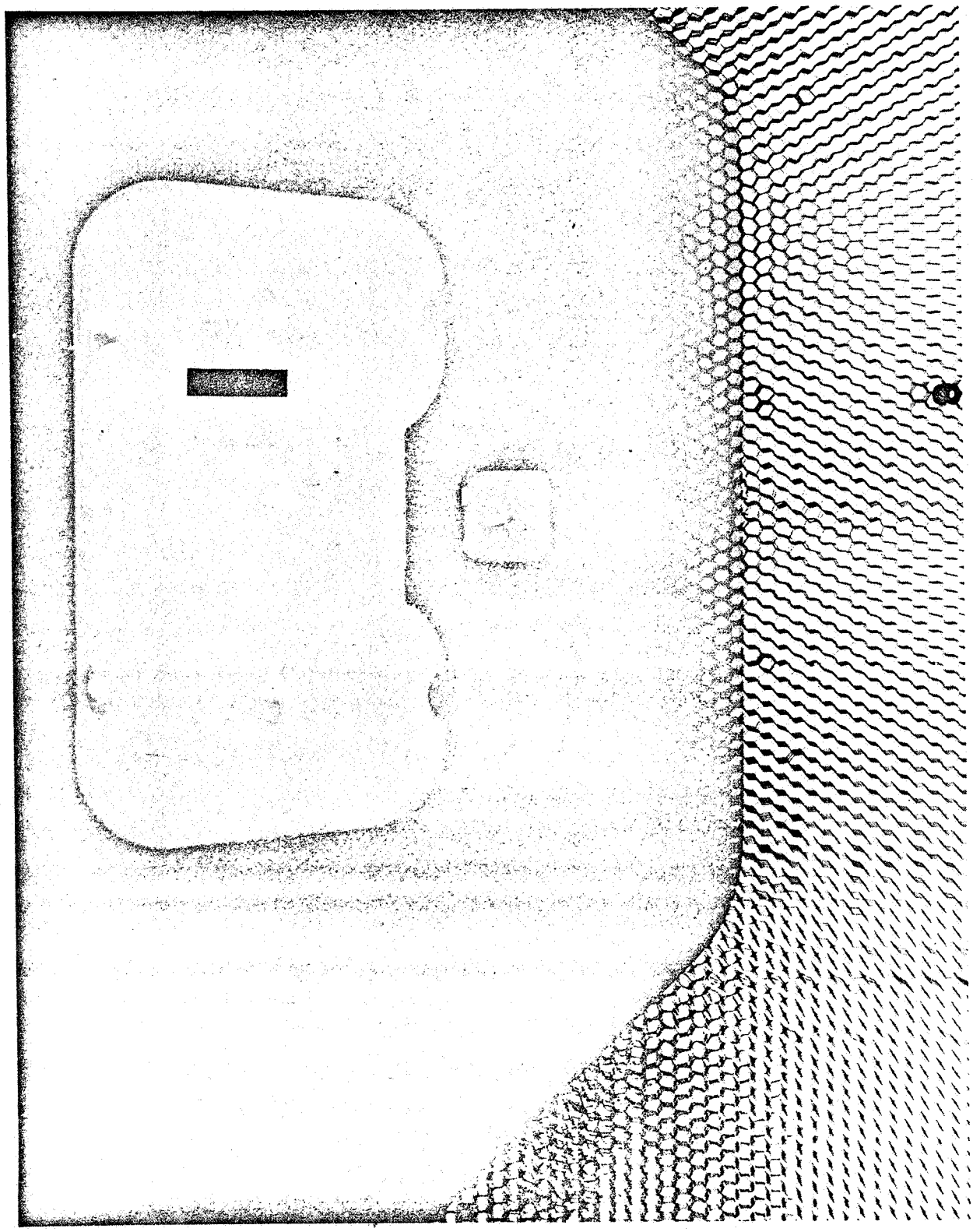

FIGURE 2.—CONTINUED

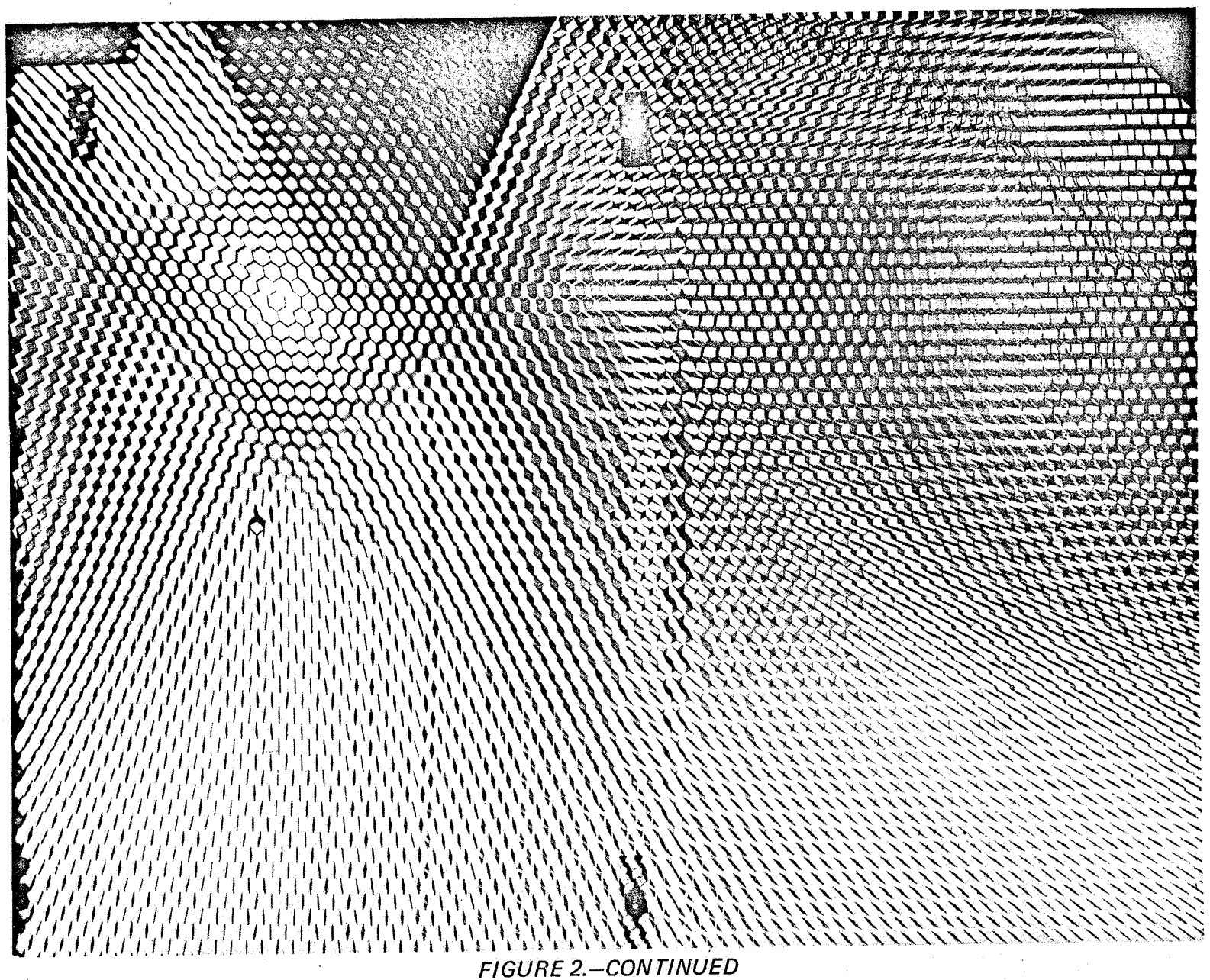

FIGURE 2.—CONTINUED

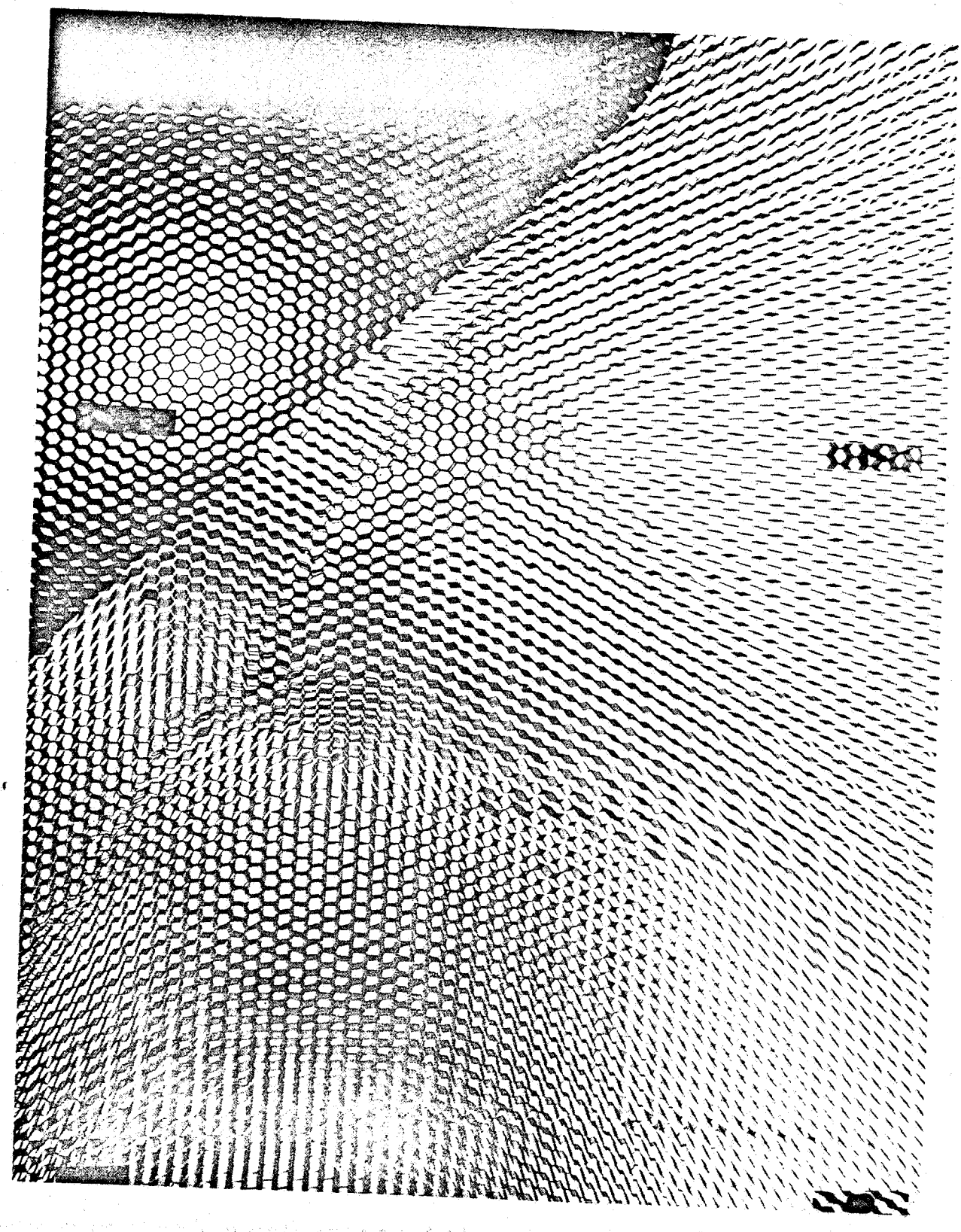

FIGURE 2.—CONCLUDED

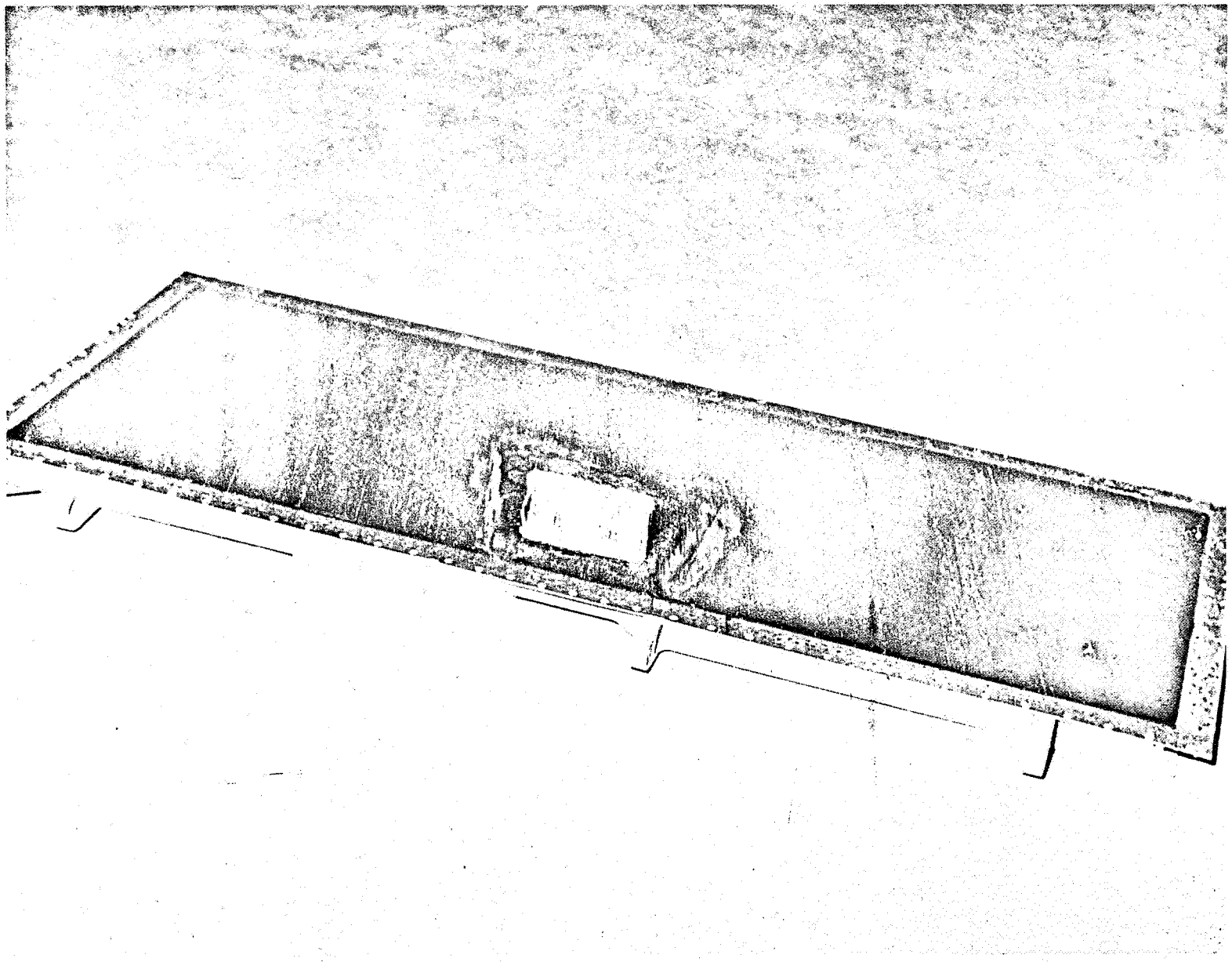

FIGURE 3.–STRUCTURAL REPAIR, STATIC TEST SPOILER S/N 0014

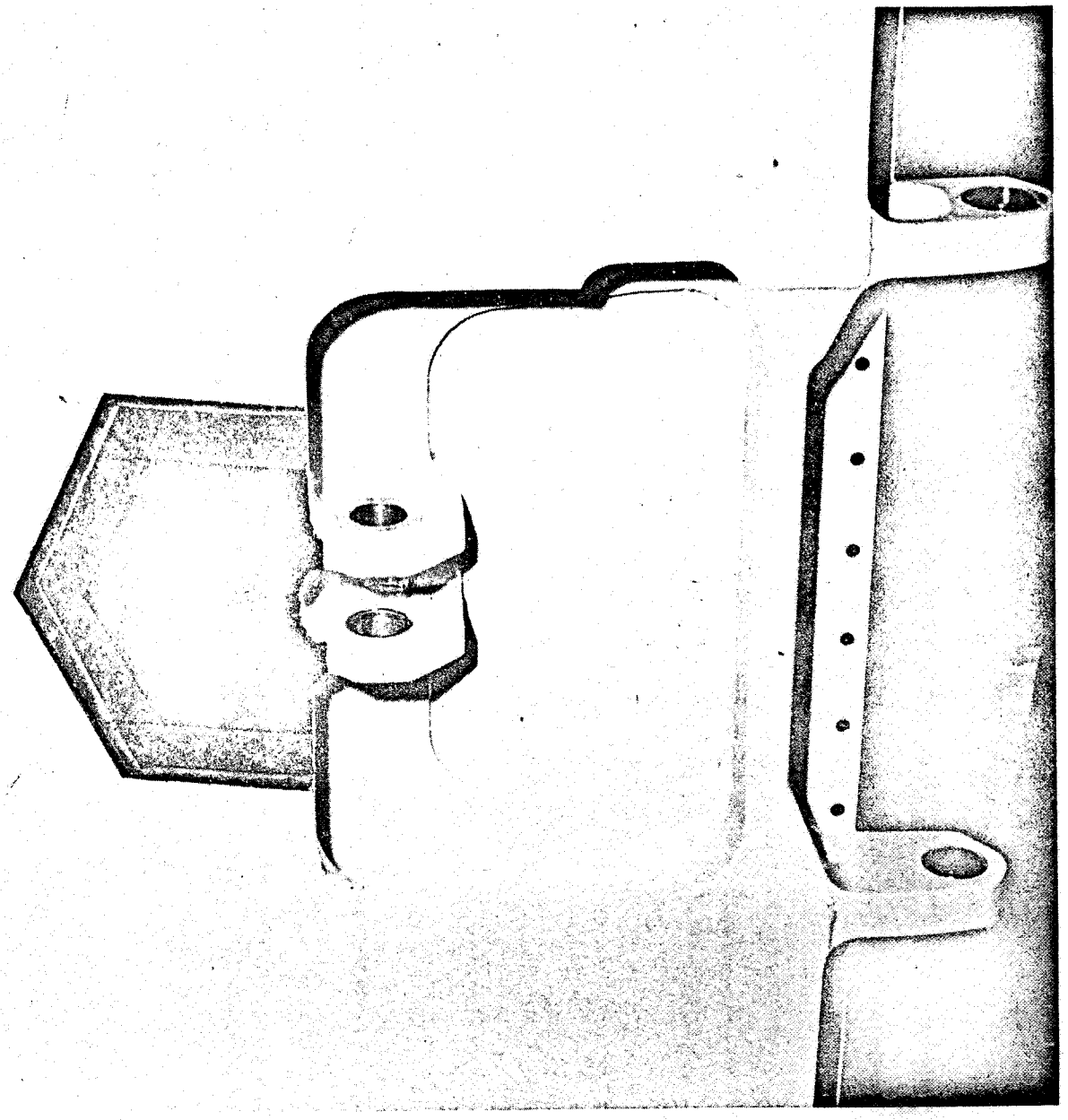

FIGURE 4.–STRUCTURAL REPAIR, UNCURED, STATIC TEST SPOILER S/N 0046

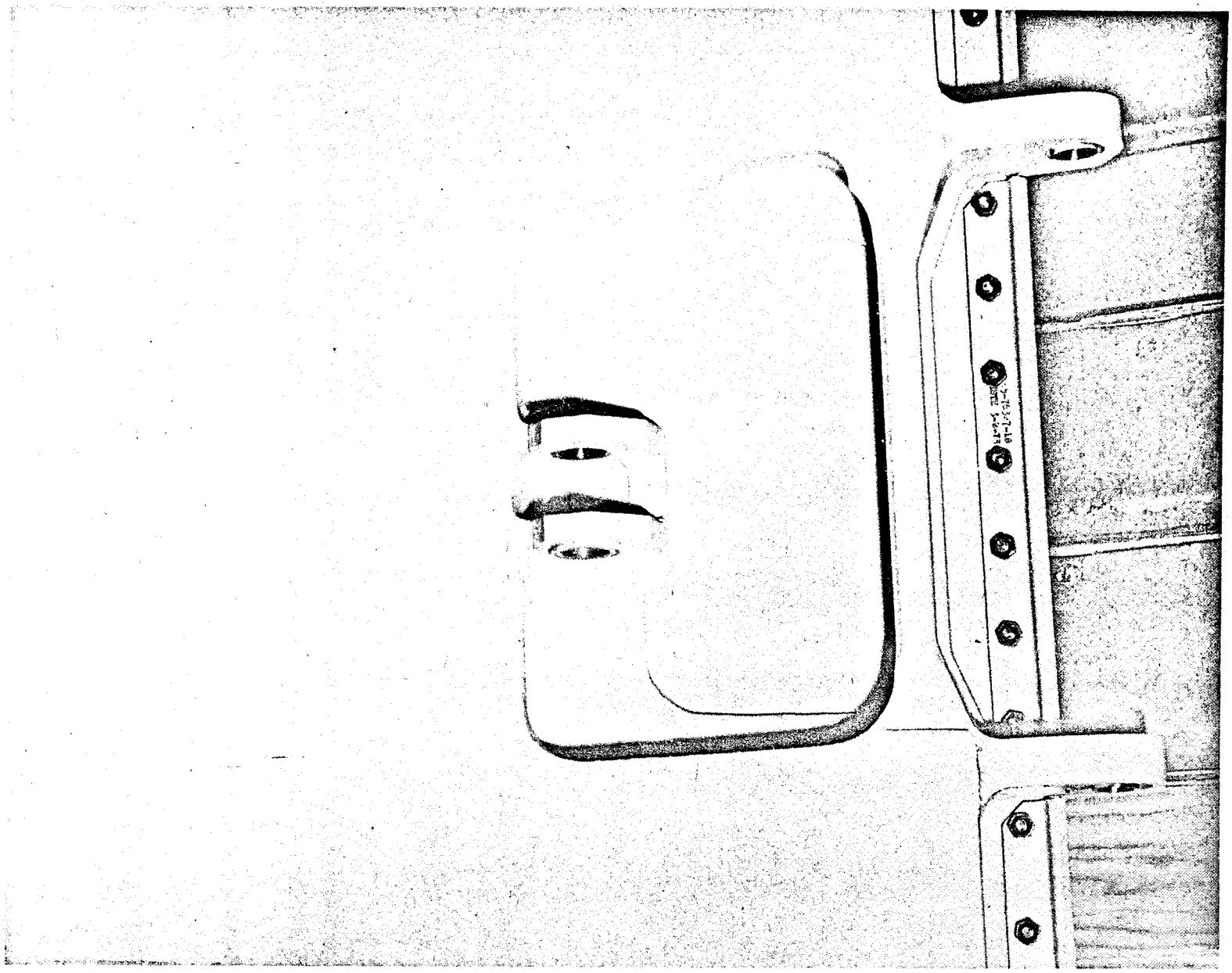

FIGURE 5.—STRUCTURAL REPAIR, CURED AND PAINTED, STATIC TEST SPOILER, S/N 0046

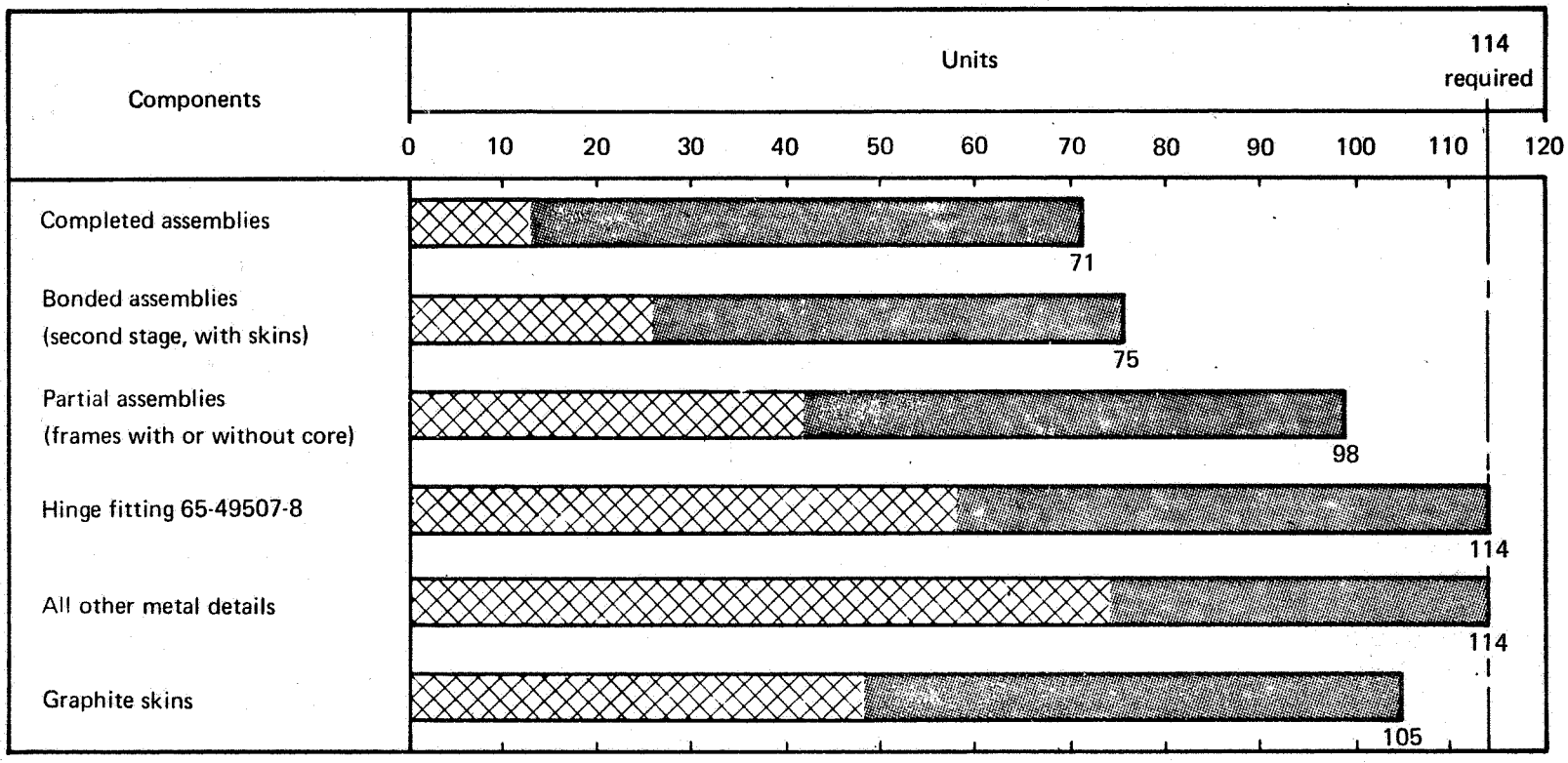

FIGURE 6.—PRODUCTION STATUS (AS OF JUNE 30, 1973)

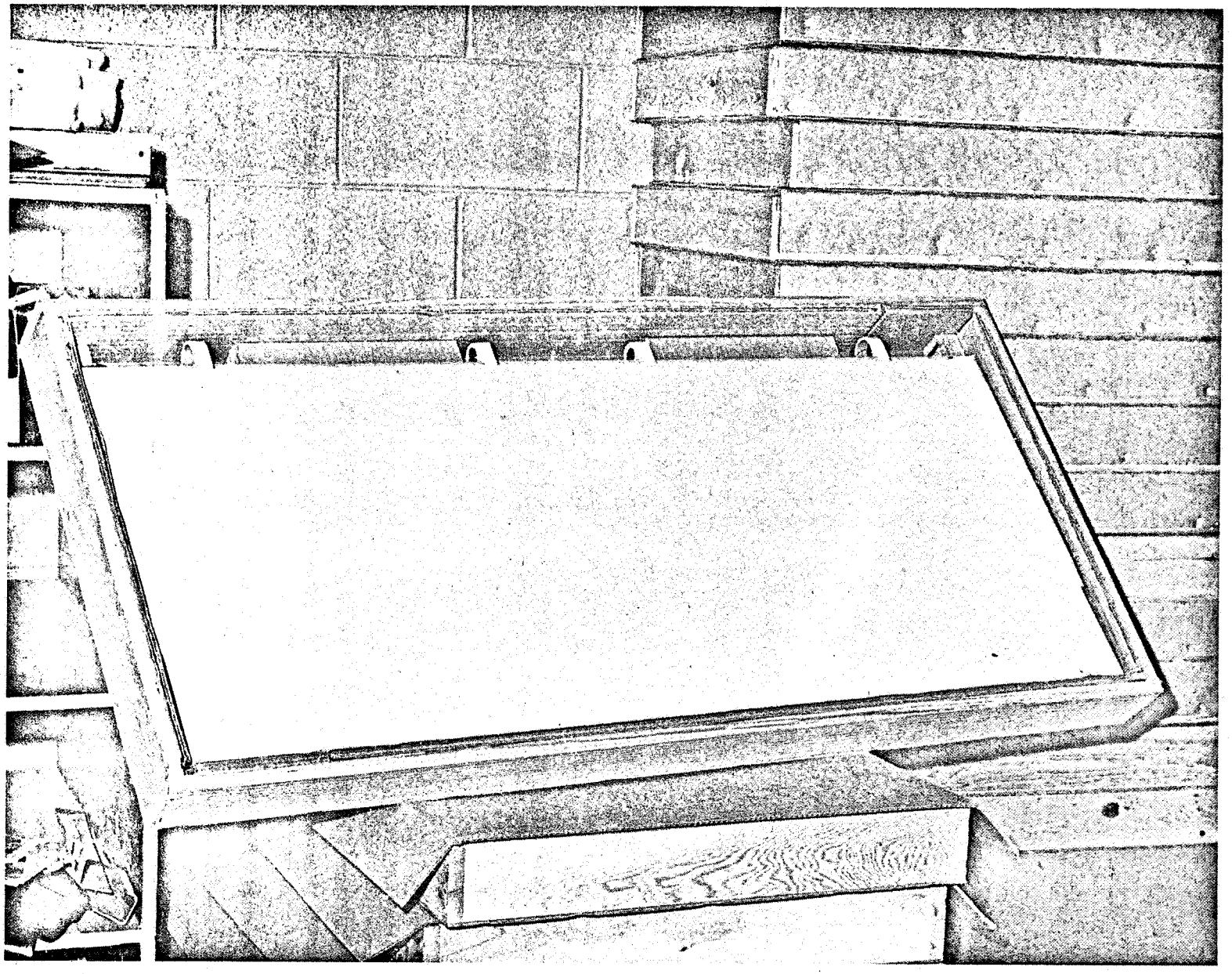

FIGURE 7.—COMPLETED SPOILER IN SHIPPING CONTAINER

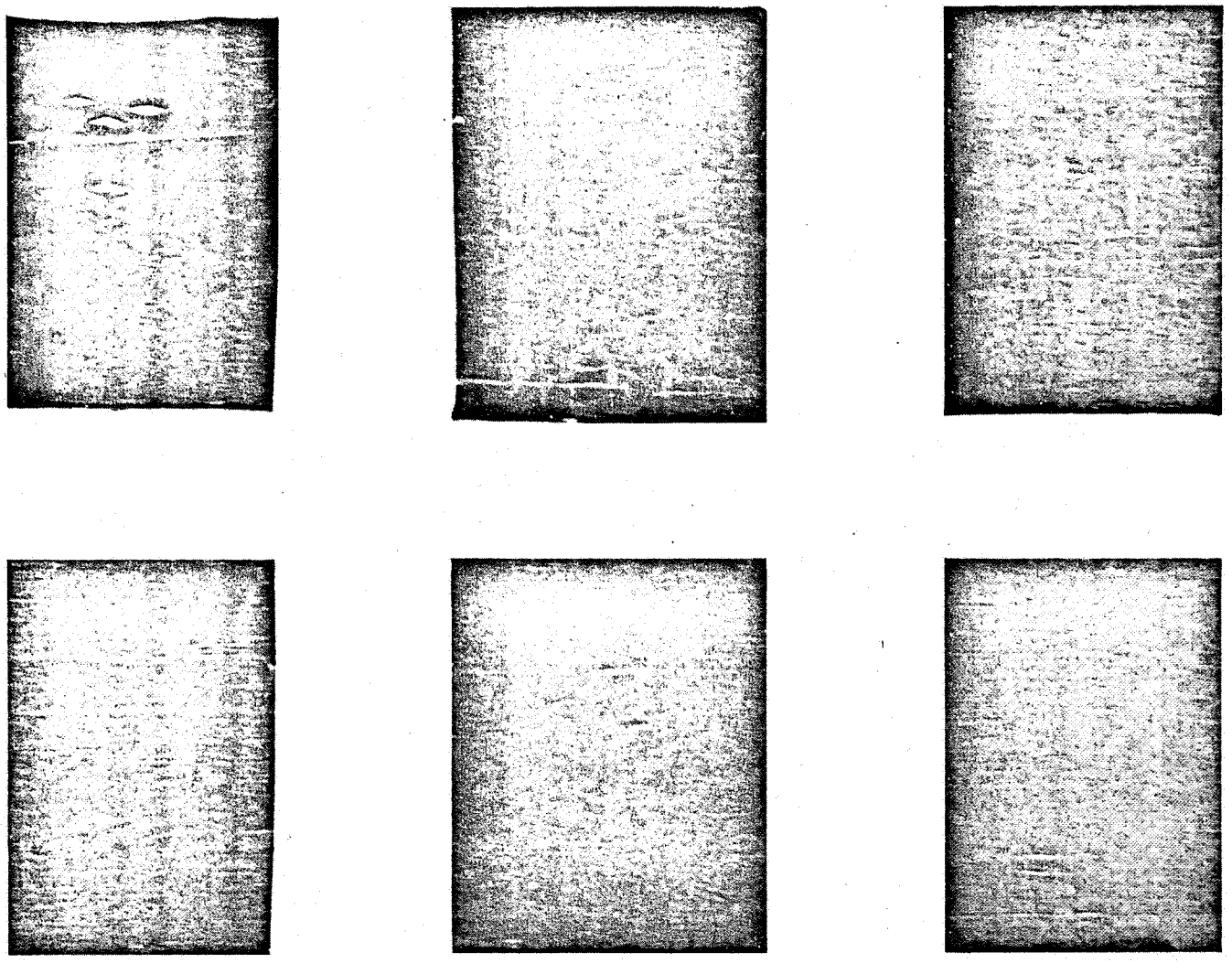

FIGURE 8.—VOIDS DUE TO LACK OF TOW ALIGNMENT

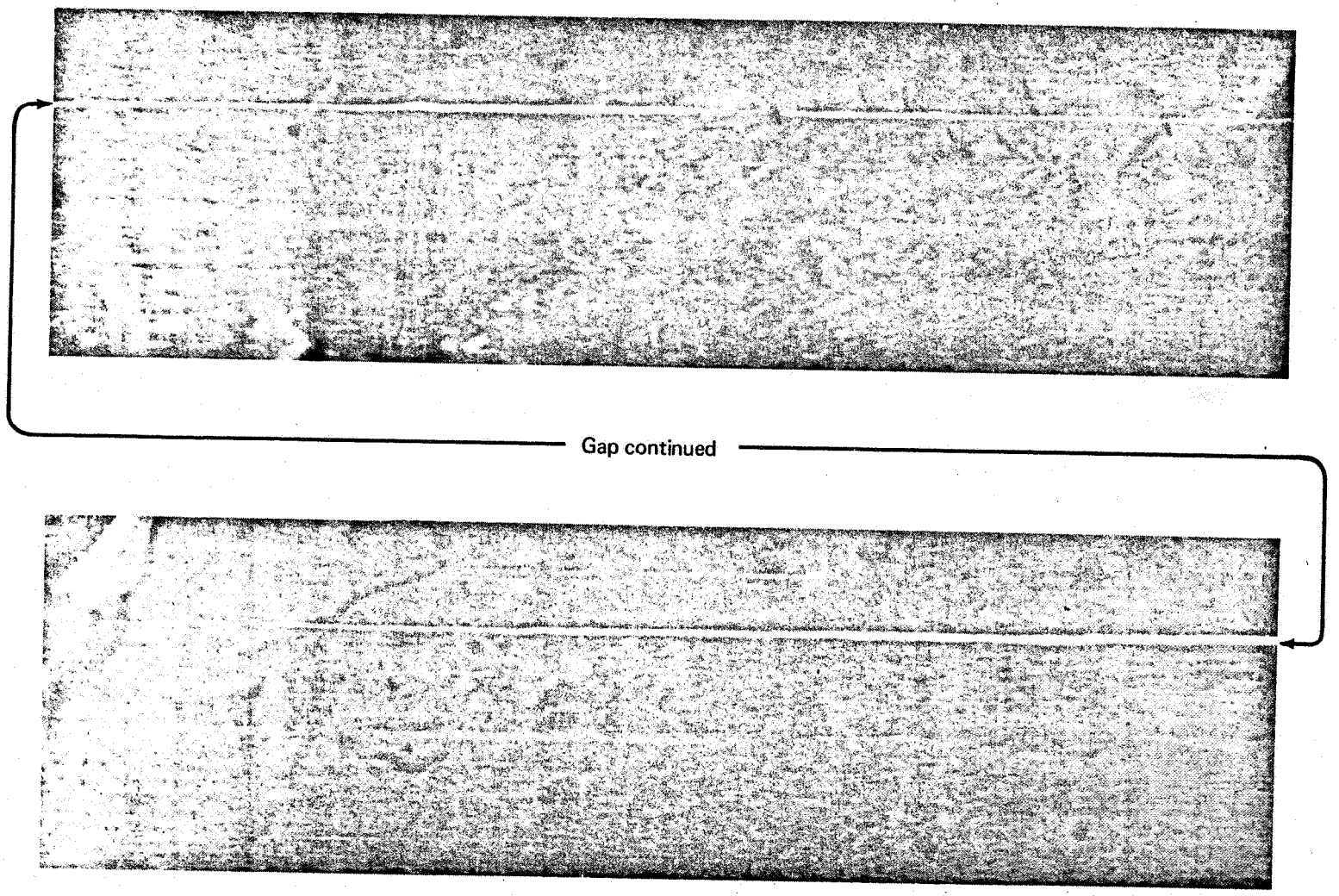

FIGURE 9.—GAP DEFECT EXAMPLE

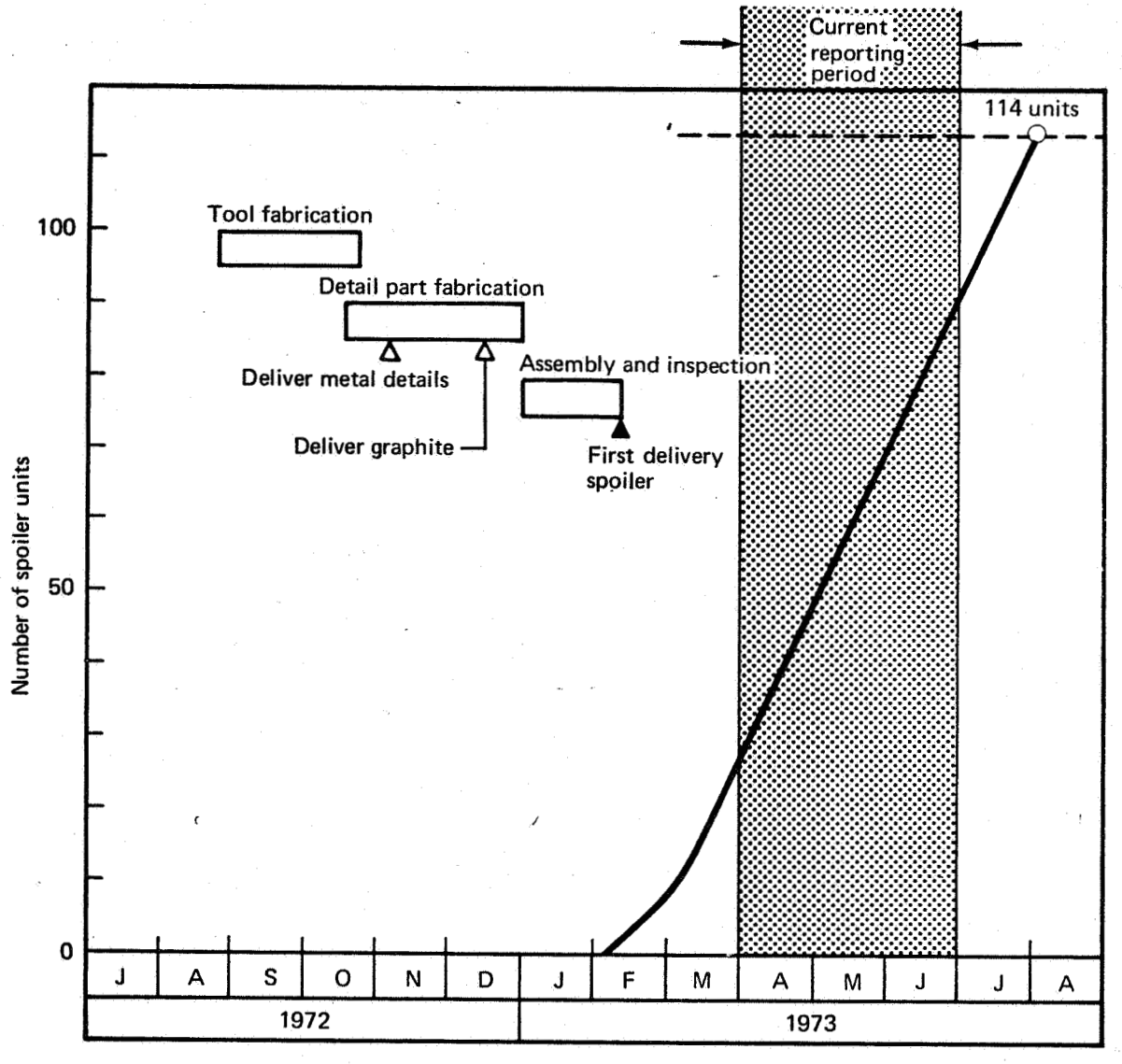

FIGURE 10.—SPOILER PRODUCTION SCHEDULE

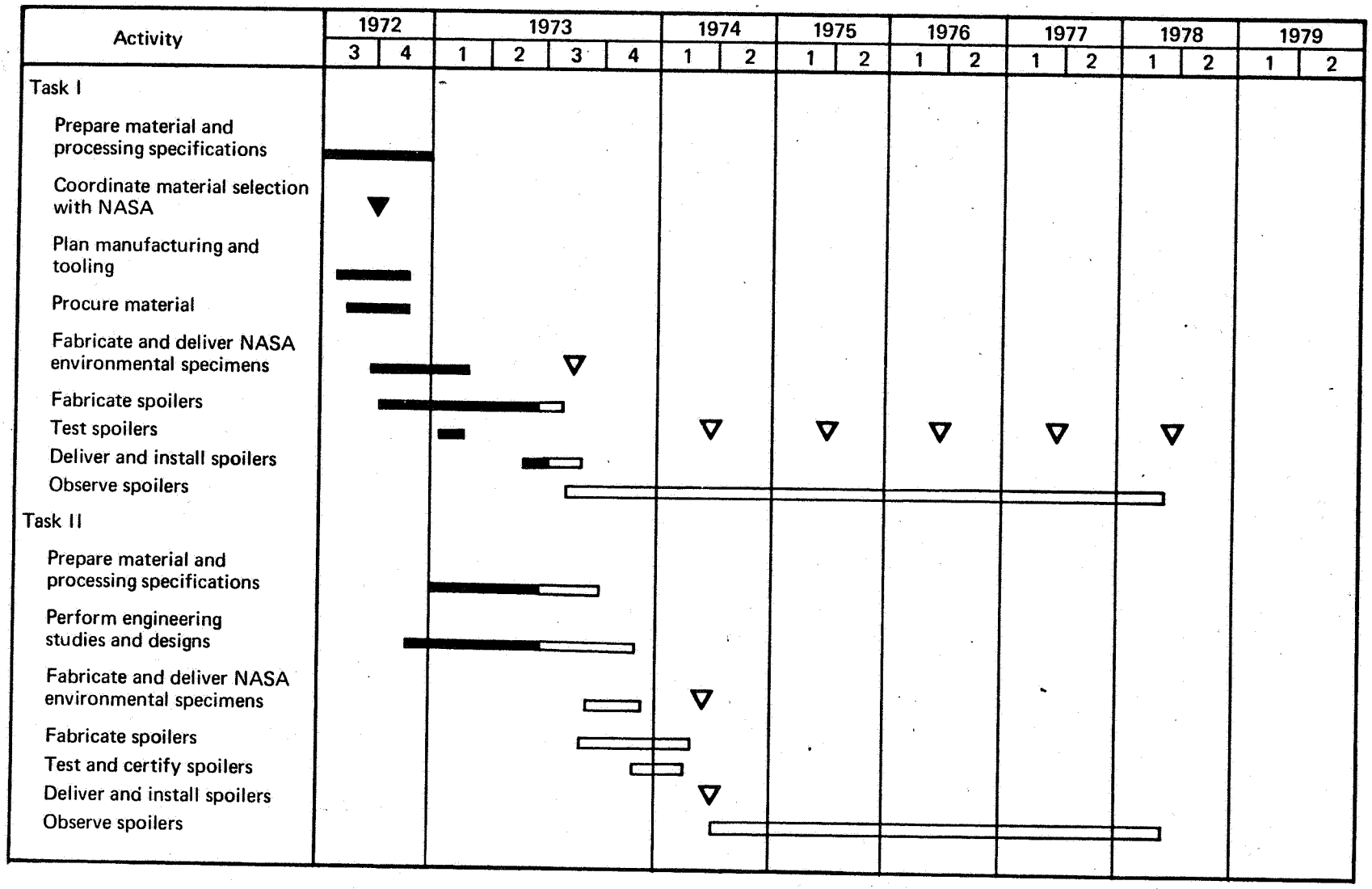

FIGURE 11.–PROGRAM SCHEDULE

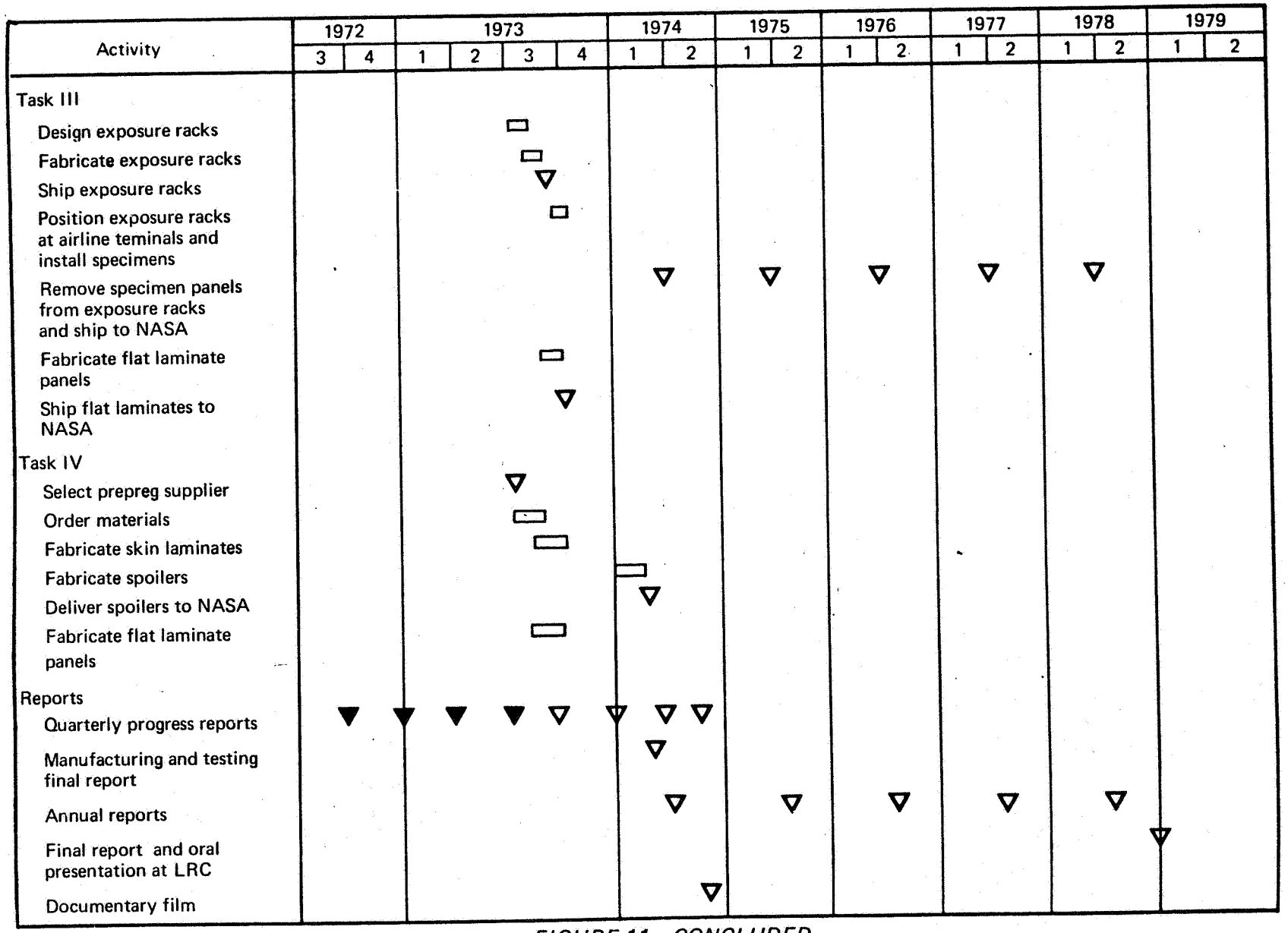

FIGURE 11.–CONCLUDED

APPENDIX

NDT PROCEDURE FOR INSPECTION OF 737 PRODUCTION GRAPHITE SPOILERS

SCOPE

This section defines the requirements for inspecting graphite/epoxy spoilers produced under NASA contract NAS1-11668. All spoilers produced under this contract will be inspected over their entirety using water-column-coupled through-transmission equipment augmented with 0-60 dB 10-level multicolor recording capability for approximately 1:1 C-scan presentation (fig. 12).

EQUIPMENT

Source

The source will consist of a high voltage pulse generator which periodically excites a transmitting transducer to emit an acoustic signal (1 MHz) of fixed amplitude and duration.

A Sperry-Rand immerscope, model 724, is recommended for the source.

Sound Couple

The sound coupling medium shall be city tap water columns of fixed pressure and flow. One water column shall proceed from the source transducer housing to the test hardware, the other from the receiver transducer housing to the opposite side of the test hardware (see fig. 13.)

Pressure and flow shall be such as to eliminate all entrapped gasses within the water column.

The water columns shall be aligned prior to test for maximum signal level.

Receiver/Signal Conditioning

The receiver shall be electronically arranged for conversion of the transmitted sonic pulse into the required electrical signal.

The output of the receiver transducer is amplified and processed in a peak detector. The dc signal developed in the peak detector is connected through logic circuitry for definition of 10

attenuation levels each 6 dB in width (0-60 dB total range). Each level activated actuates an indicator lamp and a relay/solenoid circuit for depressing the appropriate colored pen.

Data Display

The conditioned dc signal is either displayed on a CRT of a dual-trace oscilloscope or used to activate the colored pen circuits (see fig. 14).

The color code used for the attenuation levels is as follows:

Attenuation Level (dB)	Colored Pen Activated
0-6	Pink
7-12	Turquoise
13-18	Gold
19-24	Blue
25-30	Green
31-36	Purple
37-42	Orange
43-48	Red
49-54	Brown
55-60	Black

Indications above 43 dB are considered to be highly attenuated.

Scanning Mechanism

A suitable scanning table or gantry with control equipment shall be used to effect 0.040-0.080 in. steps, each 28.0 in. long, for moving the water-coupled ultrasonic transmitter/receiver yoke across the entire surface of the spoiler unit.

The selsyn controller shown in figure 14 is used to correlate movement of the pen carriage to movement of the yoke assembly across the panel.

STANDARDS

Standards shall be established for equipment alignment accuracy prior to test.

1. A 30-ply micarta block has been used during the third reporting period. This has been replaced by a 10-step polyurethane block.

2. The polyurethane block shown in figures 12 and 13 is now used to standardize the equipment. Each step or thickness variation has been previously constructed to attenuate at midrange of each decibel interval.

3. A Tektronix model 170 calibrated signal attenuator (fig. 15) is used in conjunction with the test block.

PROCEDURE

1. Turn on immerscope, log amplifier quantizer, and oscilloscope at least two hours prior to test.

2. Preset the water pressure to 20-25 psi.

   Align the water jets so that the splash pattern is perpendicular to the water flow and approximately midway between the transudcers. Check for air bubbles in the line and eliminate if present.

   The electrical signal on the DVM should be a steady 13.4 Vdc once peak voltage is obtained.

   Note: The slightest misalignment of the transducers will strongly reduce the signal received.

3. Preset the scanner stops to cover 28 in. of travel across the width of the test hardware. Set selsyn pen drive for 0.04 in. or 0.08 in. steps as required for 1:1 data display of the C-scan.

4. Place the model 170 attenuator in series with the output from the receiver transducer to the log-amp detector.

5. Place the 10-step polyurethane test block in the water path observing the signal level actuated for each step of the block (i.e., colored lights and pen solenoid actuation). If the signal level actuated varies from standard (i.e., the seventh block actuates a red pen instead of an orange one) adjust the attenuator until the proper signal level is attained. Rescan the other sections of the test block to verify that proper attenuation has been maintained. Reverify the unimpeded signal at 13.4 Vdc and ensure constant signal level when the scanner is put into motion.

6. Turn on chart drive control.

7. Place the test block in its holder and scan across each section three or four times. The colored pen presentation should be uniform for each color and change to the next highest attenuation level cleanly. Remove the test block. Retain this display on the same chart as the spoiler scan.

8. Place the graphite spoiler in the support clamp with the upper skin upward and at right angles to the source transducer. Move the transducer/water column yoke to either end of the spoiler. Set the edge stops (leading and trailing edges) so the yoke extends 1/2 to 1 in. beyond each edge.

9. Start selsyn drive and stepping motor control to start scan. Scanning time is normally 2-3 hours.

10. As yoke moves lengthwise across spoiler, index the C-scan at each 6 in. mark of the spoiler.

11. Observe and correct sticking pen solenoids whenever they occur during a scan. Lubricate with methyl ethyl ketone and graphite powder.

12. After the scan, remove the graphite spoiler and wipe dry with absorbent toweling.

13. Observe color pattern on C-scan for highly attenuated areas. Recalibrate and rescan as necessary to verify attenuation levels.

14. Store C-scan with the production planning paper for later study.

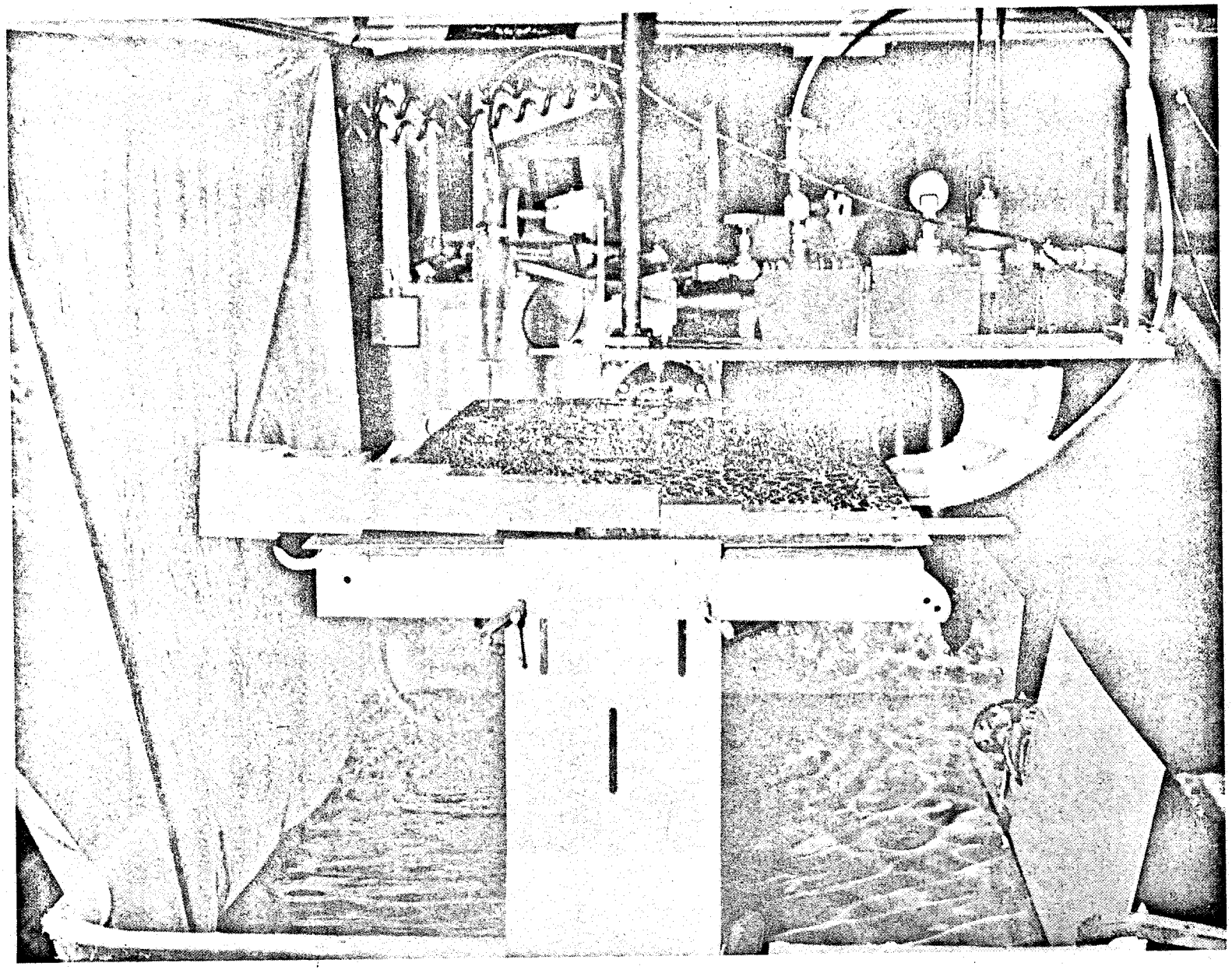

FIGURE 12 –GENERAL ARRANGEMENT–ULTRASONIC INSPECTION SETUP

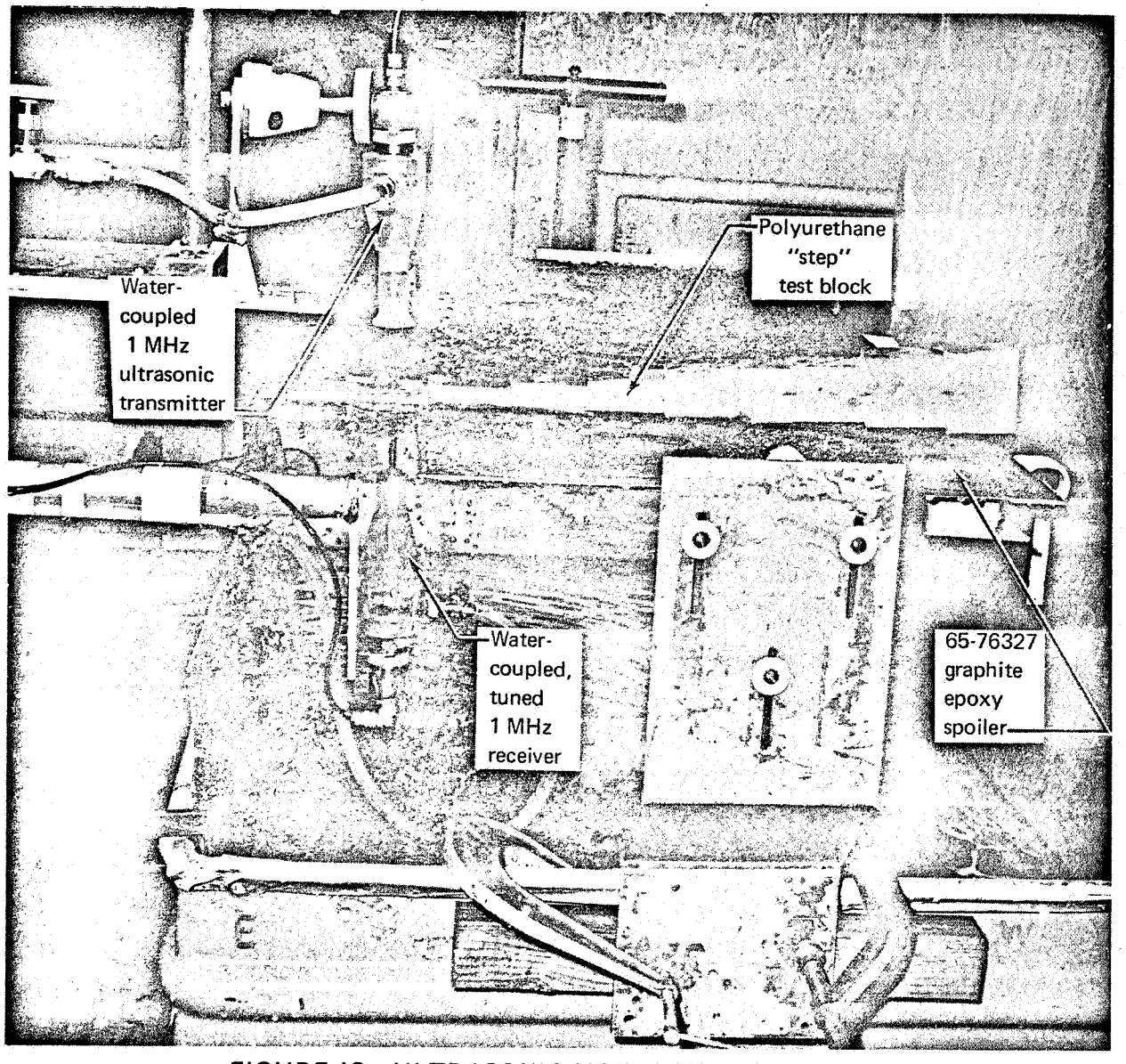

FIGURE 13.–ULTRASONIC SIGNAL TRANSMITTER AND RECEIVER ARRANGEMENT

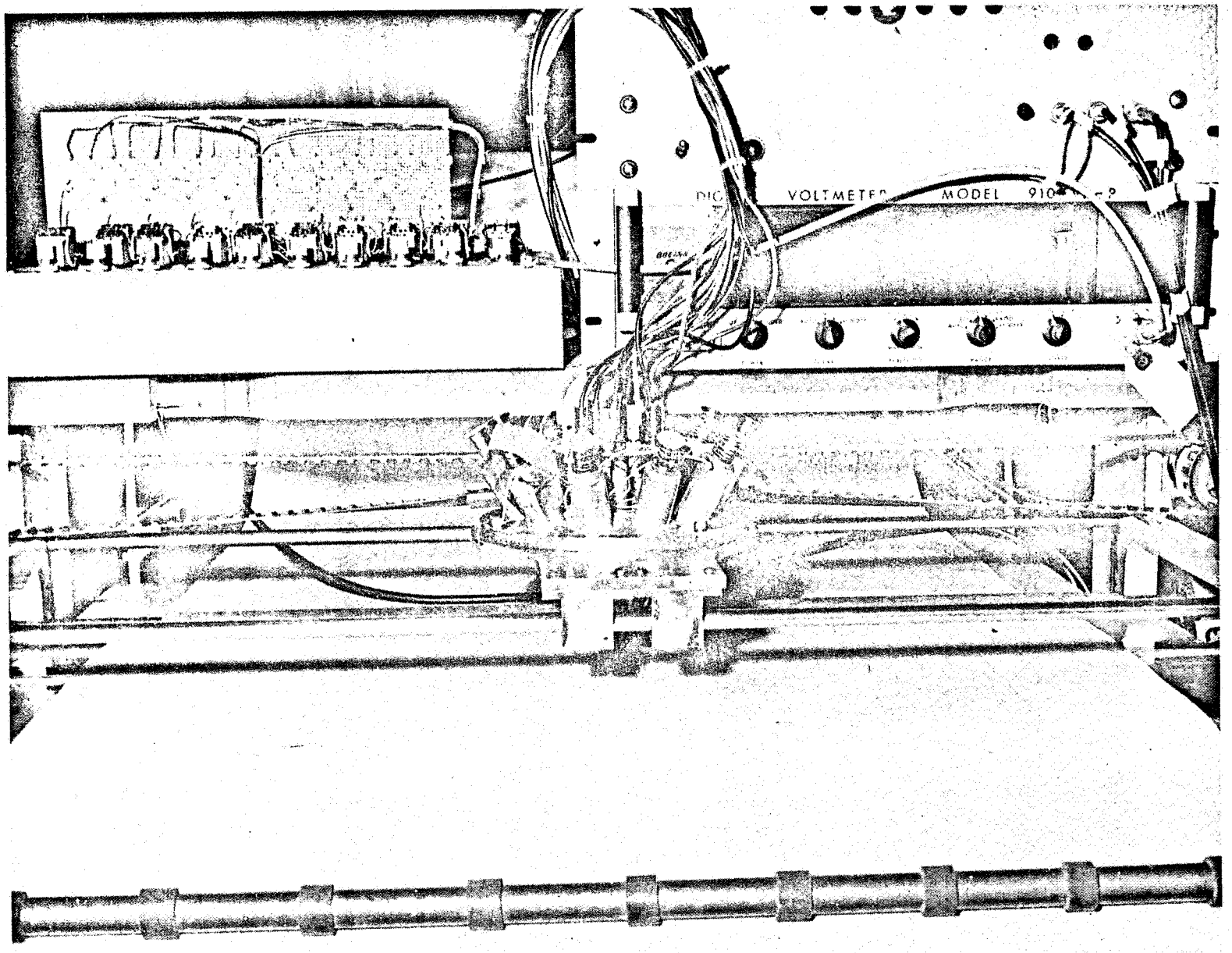

FIGURE 14.—10-LEVEL QUANTIZER AND 10 COLORED PEN ARRAY

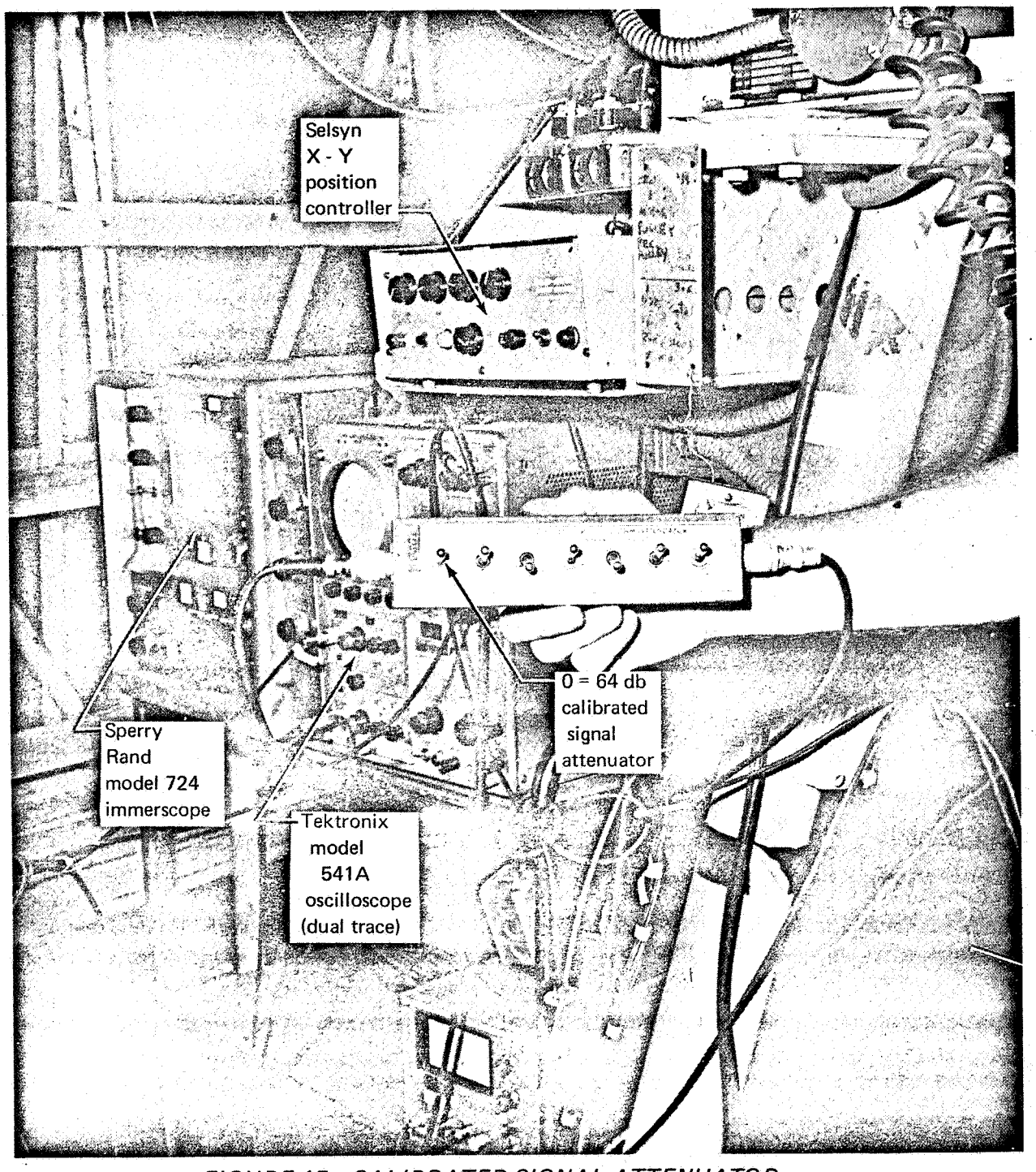

FIGURE 15.—CALIBRATED SIGNAL ATTENUATOR AND ULTRASONIC EQUIPMENT CONTROLS